OUTLINES

OF

HUMAN PHYSIOLOGY;

DESIGNED FOR THE

USE OF THE HIGHER CLASSES IN COMMON SCHOOLS.

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PREFACE.

This work is intended for those who are unacquainted with the structure of the human body. It is an attempt to explain to them the uses of its most important parts, in familiar and popular language. It differs, therefore, in this respect, from most works on physiology, which suppose some knowledge of anatomy in those who read them; and it does not treat of those topics, which, though highly important to professional students, could not with propriety be introduced into the studies of the young.

It was thought that a knowledge of the functions of the principal organs of our bodies, would be not only useful, but interesting; and that the study of human physiology might prove as agreeable as that of Botany or Mineralogy. It is difficult, no doubt, to present the subject in a form, at once popular and intelligible: it is not easy to avoid the use of technical phrases, and in some cases it is impossible to find substitutes for them. In every instance in which they have been employed in this work, however, they have been explained, and it is hoped in a manner so simple, as to render

them intelligible to every reader. It was of course a primary object to make it easy of comprehension; and when it is recollected, that it was not written for professional students, it is thought that no apology will be deemed necessary for the explanation that has been given on many points, which to them may not seem to require it.

It is hardly necessary to add, that this little work makes no claims to originality. It has been compiled with some degree of care from the best authorities on the subject, and the materials, which the labor and research of others have collected, have been freely employed. The compiler fears that it is by no means free from errors; he is aware that he could not bring to the task all the knowledge of the subject that was desirable, and he executed it while engaged to some extent in the active duties of a responsible profession. He was induced to undertake it, in the hope that it might be useful to the young; and his object will be effected, if it should open to them a new and interesting branch of knowledge. He was desirous that they should become acquainted with human physiology, as he felt confident, that they could not fail to see in the structure and functions of their own bodies, the clearest evidence of wonderful contrivance and beneficent wisdom.

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INTRODUCTION.

PHYSIOLOGY, in its limited sense, is that branch of knowledge, which explains the uses of the various organs of living beings. It is divided into Vegetable and Animal; and the latter is again divided into Comparative and Human. Comparative Physiology treats of the corporeal functions of the inferior animals; while Human Physiology of course explains those of man.

Physiologists at the present day, do not, as was formerly done, refer the actions of the living body to any one single vital principle, nor do they attempt to define life. It is known only by its properties. The most important of these are contractility and sensibility, and on these two, the others seem in great measure to depend. Contractility belongs to the muscles or the agents of motion; sensibility to the nerves, or the agents of sensation.

The vital properties not only support and nourish the body, but enable it to resist all those agents which tend to its destruction. The moment life has ceased, the body is subjected to the influence of mechanical and chemical laws. The blood gravitates in the vessels, and decomposition ensues with greater or less rapidity, according to the degree of heat and moisture to

which it is exposed. Its temperature, too, becomes the same as that of the surrounding atmosphere, though before death it was uniformly higher.

A physiological arrangemeut has been proposed, which, though perhaps not perfectly true in the extent to which it has been carried, is by no means destitute of convenience. It considers the human system as made up of two parts, in some measure distinct, and yet united in some points. One of these relates merely to the growth or organization of the body ; the other to those peculiarities, which distinguish the animal from the vegetable. The first has been called *organic life*, and the other, *animal life*. The functions of the organic life are those which tend to the preservation and growth of the individual, while those of the animal life connect him with external objects. The organs that digest the food, and those that circulate the blood, belong to the organic life, and those of the voice, the senses, and locomotion, form a part of the animal life. The organs of the first are for the most part irregular in their shape, and are not usually found in pairs. This is easily seen by examining the stomach and intestines, or the heart and large vessels.

The organs of animal life, on the contrary, are in pairs, and almost always symmetrical, those of one side of the body resembling very nearly those of the other ; and on this symmetry in some measure depends the correctness of their functions. If one eye be injured, the other sees less perfectly ; and the same is true of all the organs of animal life.

This division of the organs, into those of organic and those of animal life, though highly valuable for many purposes, is not strictly accurate in all its parts. There are, for example, some of the organs of organic life that are in pairs, and that are also perfectly symmetrical, while the symmetry is wanting in some of those of the animal life. The glands that secrete the saliva, belong to the first class; yet one is found on each side of the body exactly resembling the other. The two hemispheres of the brain, which is one of the principal organs of animal life, do not, on the contrary, always resemble each other in the size, form and number of their convolutions.

The animal body is composed of fluids and solids. The former constitute a much greater part of the whole than the latter; being in the proportion of six to one, according to Richerand, and of nine to one, according to Chaussier, in an adult subject. Various divisions have been made of the human fluids, and a very common one is that which is founded on their chemical composition. To this it has been justly objected, that the constituent elements of all the fluids are not yet known, and that of course an arrangement founded on their composition, cannot be perfect. The most simple arrangement is that which divides them into four classes, viz.: 1st, into those which form the blood; 2d, the blood itself; 3d, those that are separated from the blood; and 4th, those that are returned to it from the various parts of the body. All of these will be spoken of hereafter; the first, when treating of digestion; the second, when speaking of the heart and the

circulation ; the third, under the head of secretion ; and the fourth, under that of absorption.

The solids are formed from the fluids by a process called secretion, which will be treated of in a subsequent part of this work. Much labor and research have been bestowed on attempts to ascertain how many elementary solids exist in the various organs of the body. Some have supposed that all the solids are formed from three elementary ones, viz. : the cellular, the nervous, and the muscular ; and to these others have added the osseous and membranous. It is believed that all the organs, however various they may appear, in their structure and composition, can be ultimately reduced to these five.

These simple textures or tissues, as they are called, being united in various proportions, form the compound tissues or systems. There are eleven of these systems, according to the arrangement of Dupuytren and Richerand : these are

1. The Cellular.
2. The Mucous.
3. The Serous.
4. The Muscular.
5. The Osseous.
6. The Vascular.
7. The Nervous.
8. The Fibrous.
9. The Erectile.
10. The Horny, as the Nails and Hair.
11. The Parenchymatous, as the Glands.

It may be proper to remark, that these simple systems, by combining with each other, form what may be called the compound systems, as the circulating, nervous, and respiratory systems. A single example will perhaps make this more clear. The circulating system is composed of several parts or organs, and each of these is formed by a union of two or more of the simple systems. Thus we find in the circulating system, the cellular, serous, muscular, vascular, nervous, and fibrous systems, if no others.

Some of these simple systems will now be briefly described.

Of the Cellular System.

The cellular texture or membrane, extends throughout all parts of the body. It not only surrounds every organ, but separates the different portions of it. It takes its name from its structure, being composed of cells, which for the most part communicate with each other. It varies in density according to its situation: it is thick and firm in parts that are exposed, as under the skin on the palms of the hands and the soles of the feet; and it is of extreme delicacy in other situations, as in the brain and in the eye.

All the fat of the body is deposited in the cells of the cellular texture, and is hence called, by anatomists, cellular substance. The cells which contain the fat, it has been said by Dr. Wm. Hunter, do not communicate with each other, and of course are not the same

as those in which water and air are sometimes effused, and which communicate freely.

There can be no clearer proof of this free communication between the cells, than what is furnished by that singular affection called emphysema. Sometimes in a fracture of a rib, a portion of the bone will wound the lungs so as to form a communication between an air cell and the cellular texture. The air will then pass in respiration into this texture, and gradually extend itself all over the body. In some instances suffocation has been the consequence of the enormous swelling produced in this way.

The cellular texture forms a great portion of the body, every organ being largely supplied with it. Its chemical composition is supposed to be gelatinous, or jelly-like.

Of the Mucous System.

The mucous membrane lines all those cavities which communicate with the atmosphere, as the mouth, windpipe, stomach, and intestines. It takes its name from the fluid with which it is constantly covered in health. This fluid is secreted by numerous small glands, which are situated in the substance of the membrane. The mucous membrane is of a reddish color, highly vascular, and abundantly supplied in some parts with nervous filaments. It has important functions to perform : it is the seat of the sense of taste and smell, and contributes largely to the process of digestion.

The surface of the mucous membrane is not smooth;

on the contrary, it is covered with small folds or wrinkles, which become much larger under some circumstances, as when subjected to the action of acrid and irritating substances. Though this membrane lines internal organs, it is always in contact with foreign substances, as the food which is taken for nourishment, and the air for the purposes of respiration. It is no doubt for the purpose of protecting the system from the injurious effects of these substances, in case any of a deleterious character should be introduced, that this membrane is always covered with the viscid fluid, from which it takes its name.

Many have supposed that there is a great resemblance between the skin and the mucous membrane, and that the difference between them is rather owing to their situation than to any difference in their intimate structure. The parts of this membrane which are the nearest the exterior of the body, as the mucous membrane of the lips, are certainly very similar to the skin, and Bichat thought that if from any accident a portion of the mucous membrane should be brought upon the exterior of the body, and be kept constantly there, it would differ but little from the skin itself. But this conjecture is not confirmed by fact. In some cases of malformation, in which a portion of the mucous coat of the bladder was situated on the exterior of the body, it was found that it retained all the peculiar characters of the mucous membranes.

Of the Serous System.

The serous membrane covers on the exterior nearly all those organs which are lined with the mucous membranes, such as the stomach, lungs and intestines. It is a colorless, smooth, and delicate membrane, though possessing considerable strength and elasticity. It contains but few blood-vessels, and still fewer nerves, and consequently possesses but a small degree of sensibility in a state of health. A considerable quantity of serous fluid, from which circumstance it takes its name, is constantly thrown out on its surface; and this is done not by glands, as in the mucous membrane, but by the blood-vessels themselves, by a process called exhalation. The membrane itself having a highly polished surface, and being always lubricated by this fluid, readily answers the end for which it seems to be designed, that is, to enable the organs which it covers to move with ease upon each other.

A striking difference appears in the mucous and serous membranes when attacked by inflammation. This disease produces in the first of these membranes, if it be not severe, an increase in the secretion of its ordinary fluid, or a change in the character of the fluid; but if the disease be serious, the membrane ulcerates in spots where the inflammation is greatest.

When the same disease attacks the serous membranes, an effusion of adhesive matter takes place on the surface, which unites it to the opposite surface. This is very frequently seen in inflammation of the

membrane covering the lungs, called pleurisy: a close adhesion is often formed between this serous membrane and the serous membrane which covers the inside of the ribs. The fact that the same disease produces such different effects in the two membranes, is a remarkable proof of design in that superintending wisdom which, presides over the animal economy.

If the mucous membranes were to adhere from the same degree of inflammation which produces this effect in the serous, but few individuals would attain any considerable age. A slight cold would produce death by closing the passage to the stomach or the lungs.

The object of the adhesion in the serous membranes when inflamed, is also apparent. In health, they are in constant motion, and subjected to a great degree of friction, from which no inconvenience is experienced, as they are insensible, and constantly moistened by a serous fluid. But in disease, they become exquisitely tender, and this adhesion is formed to prevent them from moving on each other.

Of the Muscular System.

The muscles are that part of the body, which is familiarly known by the name of flesh. They are of various forms and sizes, according to their situations and the purposes they are designed to accomplish. They are made up of fibres, each of which is covered with a delicate layer of cellular membrane, and the whole muscle is again covered by a sheath. They are of a red color, which is usually attributed to the nu-

merous blood-vessels with which they are supplied. This explanation was called in question by Bichat, who maintained that the color was owing to some undiscovered property inherent in the muscle. He founded this opinion on the fact that some muscles are paler than others in the same animal, though supplied with an equal quantity of blood. His opinion, however, has not been generally received, and the difference of color, of which he speaks, has been attributed to the different degrees of exercise which the muscles receive, those being reddest which are most in action.

The muscles are the agents of locomotion, and for this purpose they are attached to the bones, which are used as levers, and the body is moved by the contraction of the muscles. They are also the agents of all the other motions of the body, and they derive their power from the nerves with which they are supplied. Haller states that the nerves which go to the thumb are larger than those sent to the liver. The action of most of the muscles, is under the control of the will; but there is an extensive class of muscular membranes, whose functions are essential to life, the action of which is wholly involuntary. They surround the stomach and intestines, form in fact one of their coats, and give them that power of motion which is necessary to the performance of their functions.

Many attempts have been made to ascertain the form of the ultimate elements of the muscles, by means of microscopical observations, but no two observers have been agreed on the point. It is fortunate that it is not important to settle it: it is sufficient to know respecting

the structure of the muscles, that they are made up of fibres.

Another subject which has occupied the attention of Physiologists, is, how far muscular contractility is independent of nervous power. It would be foreign to the character of a work so purely elementary as this, to enter at all into the examination of that question.

Of the Osseous System.

The bones are the most solid part of the body. Their uses in the animal economy are various. They form as it were a frame for the other parts, giving firmness to the whole: in conjunction with the muscles, they are the agents of locomotion, and they enclose and protect some of the most important organs of the system. In man, and in all the higher orders of animals, they are in the interior of the body, whilst in lobsters, crabs, &c., they are on the outside, forming a case which protects the other more delicate parts from injury.

Bone is composed in part of earthy matter, and in part of animal matter. By subjecting it to the action of some of the acids, the earthy part is removed, and nothing remains but the animal, yet the form of the bone is unchanged. By exposing it to the action of a moderate fire an opposite effect is produced, the animal part is removed and the earth remains, with but slight alteration in its texture.

The earthy part of bone has been ascertained to be the phosphate of lime, a substance of a very indestructible nature. The bones of animals have been found,

which apparently have undergone but little change in the revolutions of ages. Geologists teach us, that the bones of animals which perished at periods, of which there is no record, are still in existence.

The animal part of bone was supposed to consist, till recently, of gelatine; but Mr. Hatchett, of Great Britain, has proved that it is condensed albumen. Gelatine, no doubt, exists in the bones of young animals in large quantity, and is easily obtained from them by boiling.

Albumen, in a pure liquid state, is found in abundance in the white of an egg, and from this circumstance it derives its name. In a solid form it constitutes the principal part of hair, nails, and horn. It is insoluble in water, alcohol, or oils, but is dissolved by the alkalies. In a liquid state, it becomes hard by the action of heat, acids, alcohol, and some other substances.

Gelatine, in a liquid state, is known by the name of jelly; in a solid state by that of glue. It is soluble in hot water, the acids and alkalies, but is insoluble in alcohol, ether, and oils. It has been supposed to form the principal part of the cellular texture, the skin, cartilages, and ligaments; but this opinion has recently been called in question.

The bones are supplied with blood-vessels, and covered by a delicate membrane, called periosteum. They have but few, if any, nerves; certainly none of sensation, as they are destitute of sensibility in health. In amputating a limb, the patient makes no complaint while the surgeon is sawing through the bone, if it be in a sound state; when diseased, however, it is exquisitely sensible.

The bones, like all other parts of the body, are formed from the blood. The animal or albuminous part is first deposited in the exact form of the bone, and this serves as a mould to receive the earthy matter, which is afterwards added.

Of the Fibrous System.

The fibrous system is found in various parts of the body. It forms the tendons, which are the termination of the muscles, the ligaments which connect the bones, and thus form the joints, the dura-mater, the strong membrane, which covers the brain and the periosteum, or the covering of the bones. It enters also into the composition of many other organs of the body.

Though arranged in different forms, it every where possesses the same properties. It is of a dull, white color, bordering on grey; of great strength and power of resistance, with a slight degree only of elasticity; and destitute, in great measure, of contractility and sensibility. Neither absorbent vessels nor nerves have been discovered in it. In some parts of the fibrous system, as the dura-mater, blood-vessels are very abundant, while others seem to be destitute of them.

This concise account of six of the simple systems, will perhaps render more intelligible the descriptions which will hereafter be given of some of the organs. Some of the five remaining ones will be spoken of, when treating of the functions with whose organs they are most connected: thus the nervous system will be

described, when we come to speak of the sensations and their organs, the brain and nerves; and the vascular will come under notice, in the account that will be given of the circulation, and the agents by which it is carried on, the heart and blood-vessels.

In treating of the various functions of the body, those will be first examined which are connected with the nourishment and growth of the individual, and afterwards those which connect him with external objects. Among the most important of the first class is digestion.

CHAPTER I.

OF DIGESTION.

Digestion is an important part of that process by which aliment taken into the body is made to nourish it. The apparatus by which it is accomplished is of a very complicated kind. It is less so in those animals who live on substances similar to their bodies, as in the carnivorous animals, or those that feed on flesh, than in those that subsist on substances of a dissimilar character, as in the herbivorous animals, or those that live entirely on vegetables. Man can derive nourishment from almost every article of food, and on this account he has been called an omnivorous animal. His digestive apparatus is therefore less complex than that of the herbivorous animals, but more so than that of the strictly carnivorous ones.

Of the Digestive Apparatus.

This may be divided into the mouth and its appendages, the stomach and the intestines.

In the human adult, the mouth contains thirty-two teeth. There are four incisor or cutting teeth, six

canine, and six molar or grinders, in each jaw. There is another set of teeth, consisting of twenty, which begin to appear in the course of the first year after birth, all of which are usually cut by the time the child is two years and a half old, and which ordinarily become loose at about seven years of age; they then fall out, or are easily removed, in most instances, and give place to the second set. Some of the second set sometimes appear even earlier than this.

The internal part of the teeth has a strong resemblance to bone, but they have an external covering of a somewhat different character, called enamel. This substance is very hard, highly polished, insensible, and without any appearance of organization. If a portion of it be removed in any way, it is not replaced. The formation of teeth is not similar to that of the bones.

The shape of the teeth is adapted to the kind of food, on which the animals to whom they belong subsist. This is so universally true, that it has been adopted as one of the most striking characteristics in some of the classifications that have been formed of the animal kingdom.

The jaws perform an important part in rendering the food fit to be conveyed into the stomach. The upper jaw is firmly united to the bones of the face and head, and has no motion independent of them. The lower jaw is connected to those bones by ligaments and muscles, and has a joint, which allows it to perform motions of great importance. It moves not only directly upwards and downwards, so as to bring its teeth in contact with those of the upper; but it also moves laterally,

producing an effect like grinding, which crushes almost every article of food which comes between the teeth of the two jaws. The muscles inserted into the lower jaw, are of great strength; by their action alone, some persons are enabled to bite the hardest substances, and even to crack nuts with strong shells.

The tongue also assists in the process of mastication. It removes the food from one part of the mouth to another, and forms it into the most convenient shape. It is a muscular organ and possesses great power. In addition to the nerves which give it the sense of taste, it is supplied with a pair of very large nerves, called the ninth pair, with apparently no other purpose than to increase its muscular energy.

Three pairs of glands pour the fluid which they secrete into the mouth. This fluid is called saliva, and is an important agent in the first part of the process of digestion. The largest of these glands are called *parotid*, from being situated about the ear. The tube which conveys their secretion into the mouth, pierces the muscle in the cheek, and has been called the duct or canal of Steno, from an anatomist who described it. It is this gland which is the seat of the disease known by the name of the Mumps. The sub-maxillary glands are situated under the lower jaw, and the sub-lingual under the tongue. An obstruction in the duct of one or both of the sub-maxillary glands, produces that singular affection which is called ranula or frog-tongue. It consists of a swelling, sometimes of the size of a pigeon's egg, resembling a bladder, situated directly under the tongue. It is not unfrequently met with in chil-

dren. It is computed that no less than eight ounces of saliva are poured into the mouth, from these different glands, at every full meal.

a Parotid Gland. *b* Duct for conveying the saliva into the mouth.

In immediate connexion with the mouth, and situated in the posterior part of it, is the pharynx, so called, which is the commencement of the passage to the stomach. It is of an irregular form, being considerably larger at its upper, than at its lower extremity. Its continuation is called œsophagus, which is of a cylindrical shape, and of nearly an uniform size. It extends from the pharynx to the stomach. Both of these passages are lined by the mucous membrane, which is surrounded by muscular fibres, and supplied with nervous filaments and blood-vessels. It is by the means of the pharynx and œsophagus that the act of deglutition or swallowing is effected.

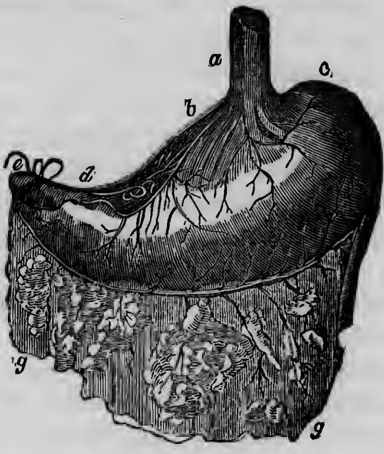
The stomach is the largest organ of digestion. It is of an irregular shape, and closely resembles the bag of

a bag-pipe. It lies directly across the body, just under the diaphragm or great muscle which separates the chest from the abdomen. The œsophagus enters it in the upper part of the left extremity, which is much larger than the right. The opening into the stomach is called the cardiac orifice, and the opening from it into the intestines is called the pyloric orifice. The stomach of an adult in an ordinary state of distention, is capable of holding about three pints. It was formerly described as consisting of many coats; each of the different layers of cellular membrane which exist between the coats, being considered as a distinct one. Exclusive of the cellular coat, it has three. The first is the mucous coat which lines it: this coat contains a great nnmber of small glands, by which not only the ordinary mucus is secreted, but which are supposed to furnish the gastric juice, a very important agent in digestion. Immediately under the mucous coat, numerous muscular fibres are found, some of which run in a longitudinal direction, and others in a transverse; and these form the muscular coat. Exterior to this is the serous coat, forming a smooth and highly polished covering.

The stomach is abundantly supplied with blood-vessels and nerves,—an evidence of the important part it is designed to perform in the vital functions. Its nerves are derived from a variety of sources; some from what are called the ganglions; others from the spinal marrow, and what is still more remarkable, a pair is sent from the brain itself.

At the pyloric orifice of the stomach, there is a

membranous fold, which acts something like a valve, and which is supposed to be capable of preventing the



THE STOMACH. *a* Œsophagus. *b* Cardiac portion. *c* Great or left extremity. *d* Small extremity. *e* Stomach, tied at the pylorus. *f* Great anterior curvature. *g* Omentum or caul.

exit of its contents till they have been sufficiently acted upon, for the purposes of digestion.

The intestines in the human subject are usually from six to eight times as long as the individual to whom they belong. They are divided into small and large intestines, the former constituting about four-fifths of the whole. The small intestines are divided into the duodenum, the jejunum, and the ileum. The duodenum is so called from its length being about equal to twelve fingers in breadth. It is somewhat larger than the other two. The ducts from the pancreas and liver enter into it, usually at about one-third of the distance between the

stomach and the jejunum. Sometimes they enter separately and sometimes by a common opening. The duodenum is abundantly supplied with absorbent vessels, called lacteals, from the resemblance of the fluid they contain to milk.

There is no marked difference between the jejunum and the ileum. On the mucous surface of both, there are small follicles, called the glands of Peyer, Brunner, and Lieberkuhn, and they both contain many absorbent vessels; they are not so numerous, however, as in the duodenum.

Where the ileum enters the large intestines, there is a valve, so as to prevent the return of the intestinal contents into the stomach. All the intestines are supplied with three coats, similar to those of the stomach.

Of the Digestive Process.

Mastication and deglutition are intimately connected with digestion. As soon as the food is taken into the mouth, it is cut by the incisor teeth, or ground by the molar ones, according to the nature of it, into minute parts, and in this way becomes intimately mingled with the saliva. The powerful contraction of the muscles which move the lower jaw, in mastication, increases the flow of this fluid. A large quantity of saliva, is at all times poured into the mouth, but so long as we swallow with ease, we are not aware of the amount of the secretion. But this becomes evident the moment the throat is inflamed, or deglutition is difficult from any cause. The presence of savory food in the mouth, increases to a

great degree the action of the salivary glands, and if mastication be properly performed, every particle of food is completely surrounded with saliva. It is then carried by the action of the tongue and the muscles of the mouth into the pharynx. This part of deglutition is voluntary; but the passage of the food through the pharynx is wholly involuntary, and is performed very rapidly, so that no part of it may enter the wind-pipe, over which it passes.

To prevent the introduction of any portion of the food into the air-passage, a very simple, and, at the same time, a very effectual contrivance has been adopted, There is attached to the root of the tongue, a small cartilaginous body, called epiglottis, as it is intended to cover, under certain circumstances, the glottis, or opening into the larynx, the organ of voice. The ordinary position of this little organ, is perpendicular, so as not to obstruct the passage of air to the lungs. But in the act of swallowing, the tongue is carried backwards, and the epiglottis is brought directly over the glottis, so as to completely close it. It remains in this state till the food has passed over it, and it is then restored to its ordinary position by the relaxation of the muscles, and its own elasticity. As the passage of the air to the lungs cannot with safety be long interrupted, it is necessary that this part of swallowing should be, as we see it is, rapidly performed.

As soon as it enters the œsophagus, it is carried slowly downwards towards the stomach. The muscular contraction by which it is accomplished, is powerful, sufficient to overcome a very considerable degree of

resistance. It then enters the stomach, and there undergoes a change, by which it is brought into a homogeneous mass, neither fluid nor solid, which is called chyme. There has been great diversity of opinion among physiologists as to the mode in which this was effected.

Hippocrates, who made the first attempt to explain the digestive process, believed that the food was converted into chyme, by what he called coction. This opinion was adopted by Galen, and prevailed for some centuries. It is probable that he attached to the word coction no very precise meaning, but used it merely as a substitute for that of digestion. If, however, he intended to imply by the term, that anything like boiling went on in the stomach, he obviously labored under a very great mistake. A decisive objection to this notion, is that the temperature of the body is not sufficiently high; and even if it were, the effect produced on the food by the stomach, is not similar to that arising from boiling. It is probable, however, that the ancients employed the term coction in explaining digestion, to veil their ignorance of the subject, without giving to it the precise meaning that some of their followers have since attempted to do.

The next theory of digestion that attracted much notice, was that which taught that the food underwent a putrefactive process in the stomach. The facts in opposition to this are unanswerable. There are many birds and other animals of prey, that feed on carrion in the most putrid state, and it has been repeatedly ascertained, that when flesh has been taken into the stomach

in this state, it becomes perfectly sweet after remaining there some time.

A bird in attempting to swallow a pike, has died by choking. When found in this situation, that part of the fish which remained in the throat was putrid, while that which had entered the stomach was wholly untainted. No one in modern times has given the slightest countenance to this theory, with the exception of Cheselden the celebrated English anatomist.

The next theory that was brought forward was a mechanical one, and all the phenomena of digestion were accounted for by trituration. This notion was first suggested, no doubt, to the supporters of the doctrine, by the known action of the gizzard in some species of birds, and a supposed analogy between the offices of this organ and those of the human stomach. But the fact is, that the gizzard does not correspond to the stomach, but merely takes the place of the teeth, those animals who are furnished with a gizzard being destitute of them. This circumstance, however, was overlooked by the disciples of this theory, and nice mathematical calculations were made to show the prodigious power with which the stomach could act upon its contents. It is really amusing to see how widely different were the results at which these calculators arrived; one of them estimated the muscular power of the stomach to be equal to 12,951 pounds; another thought it to amount to about 20 pounds; and a third reduced it down to five ounces.

They chose also to overlook a well-known fact, that while many hard and tough substances are easily di-

gested, the pulp of a grape will very often at the same time pass through the stomach without undergoing any change.

Some experiments of Abbe Spallanzani and others, which will be particularly spoken of hereafter, render it certain that food can be digested in the stomach without the slightest mechanical pressure of that organ.

When the mechanical theory of digestion was abandoned, another, which may be called a chemical one, took its place. This attributed the whole process to fermentation. If this were true, food should undergo the same change out of the stomach, when subjected to the same degree of heat and moisture, that it does in. But this is not the case ; the chemical laws seem to be controled and modified by the laws of the living body.

The doctrine that was supported by the celebrated Haller, maintained, that digestion was effected by maceration, the food being confined in the stomach, and subjected to an uniform temperature, and constantly immersed in fluid. There are two objections to this ; the first is, that maceration is a much slower process than digestion ; and the second is, that in maceration the nature of the substances macerated remains unchanged, which is not the case in digestion.

The opinion that is now most generally received respecting the mode in which the stomach acts on the food that is taken into it, is, that a peculiar liquor secreted by the stomach, and called gastric juice, has a solvent power, which enables it to reduce the food to an uniform mass. This is sometimes called the theory of

chemical solution. This solvent power seems to have been satisfactorily proved by the experiments of the Abbe Spallanzani, which were before referred to. He believed that the gastric juice varied in different animals according to the nature of the food on which they fed; that that contained in the stomachs of animals strictly herbivorous, differed from that of the carnivorous animals. He obtained quantities of it, at different times, from various animals, and subjected it to very minute examination: he denied that it was either acid or alkaline; but nothing satisfactory is yet known of its nature: it has been repeatedly examined since his time by acute observers, and no two have arrived at the same conclusions.

The solvent power of the gastric juice, he proved by many experiments. He caused animals to swallow tubes with holes in them, containing food which had been previously chewed, and he found that it was converted into chyme.

He tried similar experiments on himself. He at first swallowed wooden tubes, into which he put various articles of food; but as these produced pain in the stomach, he substituted linen bags, and found that their contents were invariably digested. This he attributed to the solvent power of the gastric fluid, which penetrated the linen, and dissolved the food. As some mechanical pressure might have been made on the bags in this case, Dr. Stevens of St. Croix, then in Edinburgh, devised an experiment, which obviated this objection. He caused some hollow metallic balls to be made, perforated with holes, and into these balls he introduced food that had been masticated. These were swallow-

ed, and, when subsequently examined, were found entirely empty.

It is therefore certain that the gastric juice, while in the stomach, is capable of dissolving food taken into it. But Spallanzani ascertained, to his own satisfaction at least, something further. He mixed some masticated food with the liquor of the stomach in a glass tube, and placed it in his arm-pit, that it might have about the same temperature as if it had been in the stomach. At the expiration of a number of hours, varying in his different experiments from fifteen to forty-eight, he found, he says, that the food was converted into chyme.

This experiment, however, has been often repeated since, but the same result has never been obtained. The food not only has not been converted into chyme, but the gastric juice employed in the experiment has frequently become putrid. This is what might have been expected; for it is difficult to believe that the process of digestion is dependent on chemical laws alone: on the contrary, it can hardly be doubted that these are controled by the laws of vitality, which preside over the functions of the animal economy.

The gastric juice, though evidently possessing a strong solvent power, seems to be incapable of acting on anything endowed with life. Worms, while living, will often remain in the stomach uninjured, at a time when the hardest substances are undergoing solution; but the moment these animals are dead, they are dissolved by the gastric liquor.

Mr. Hunter has stated some remarkable facts in relation to the solvent power of this fluid. In some per-

sons, who have died suddenly without previous disease, and after long fasting, the stomach has been found perforated with numerous holes. The only satisfactory explanation seems to be, 'that the stomach itself is partially digested by the gastric juice, which had been previously secreted.'

The gastric liquor has also the property of rendering solid, or coagulating, as it is termed, liquid albuminous matter, when it is mixed with it. On this property depends the process by which cheese is made. Rennet, which is employed for this purpose, is an infusion of the fourth, or digestive stomach of the calf, and Dr. Fordyce ascertained that six or seven grains of the 'inner coat of this stomach, after being infused in water, afforded a liquid, which coagulated more than one hundred ounces of milk.' It has been ascertained, that milk, and all other albuminous fluids, are coagulated in the stomach by the gastric liquor; and the appearance of curd, in what is sometimes thrown from that organ after milk has been taken into it, is no indication of disease, as the coagulation of milk, or its formation into curd, is the first step in the process of digestion.

No change, except a mechanical one, takes place in the food in the first hour after it has been conveyed into the stomach. During that period, it becomes intimately mixed with the gastric juice, which seems to be an essential preliminary step in the digestive process. This is easily and thoroughly effected if the food has been properly masticated; but it cannot be readily done, unless we eat slowly, and chew the food sufficiently long to divide it into very minute parts.

The introduction of food into the stomach, produces an increased secretion of the gastric liquor, which is poured out in such abundance in health, as to surround every particle of it. When this is accomplished, an alternate contraction and expansion of the stomach takes place, and continues till the whole alimentary mass is converted into chyme. This motion is produced by the muscular coat of the stomach, which is formed, as has been before stated, by muscular fibres running in a longitudinal and transverse direction.

It has been ascertained, that in a healthy stomach, the food, if easy of digestion, is converted into chyme, in four or five hours, and that before this change has taken place, it is prevented from passing into the intestine, by a sort of valve situated at the pyloric orifice of the stomach, called pylorus, or door-keeper. It has been supposed by some, that this valve has the property of determining when the aliment was sufficiently changed to allow it to pass, that it gives free exit to chyme, and contracts when undigested substances attempt to enter the duodenum.

The food is not all converted into chyme at the same time; but as fast as it is changed, it passes into the intestine, only two or three ounces collecting in the pyloric extremity at once.

The change which the alimentary mass undergoes in the first intestine or duodenum, as it is called, is as great and important as the one which is effected in it in the stomach. In that organ, it is converted into chyme, and the process is called chymification: in the intestine, it undergoes what is called chylification; in which, it is

brought into such a state, that a peculiar fluid, called chyle, can be extracted from it by the absorbent vessels, whose mouths open in great abundance into this intestine. This chyle is a thin milky fluid, and these absorbents are thence called lacteals.

The chyme passes slowly through the duodenum, and in its passage it becomes intimately mixed with the liquor secreted by the pancreas or sweetbread, and the bile which is formed by the liver. These fluids sometimes pass through separate tubes, and at others enter by a common canal. The inner coat of the first intestine is covered with folds of its lining membrane, which answer the purpose in some measure of valves, retarding to some extent the passage of the chyme, and preventing, under ordinary circumstances, its regurgitation. In this way, the absorbents have an opportunity of separating from it the chyle, the fluid which is afterwards to be converted into blood, for the nourishment of the body.

The chyle has frequently been examined, with a view of ascertaining its nature and properties. It has no inconsiderable resemblance to cream in appearance, and when removed from the body and suffered to stand, it undergoes a species of spontaneous coagulation. It separates into three parts, a transparent and colorless fluid, a firm and white coagulum, and a thin pellicle of fatty matter, which floats on the surface; a process not unlike that, which will be hereafter spoken of, as taking place in the blood when removed from the body.

It has also been found, upon analysis, that its constituent principles resemble those of the blood, in some of their properties. The same salts are found both in

the chyle and the blood; but the chyle contains a very considerable quantity of fatty matter, which rarely, if ever, exists in the blood.

Another point of resemblance between these two fluids, is the existence of globules in the chyle, which has been ascertained by microscopical observations, and which resemble the red globules of the blood.

The chyle differs somewhat, according to the food on which the animal from whom it is obtained, has subsisted. If the food has contained a considerable portion of fat, the chyle will be of a white milky appearance; but if it contained a very small quantity of it, it will be semi-transparent, and a thinner pellicle will form on the surface when it is permitted to coagulate.

The chyle is not changed in color, by the color of the food on which the animal is fed: a different opinion has been maintained, but the point has been fully determined by numerous experiments.

It is not satisfactorily settled how the process of chylification is effected. It seems to be probable, however, that the liquor from the pancreas and the bile are important agents in the process. It has been ascertained, that the chyme is not changed till it reaches the orifices of the pancreatic and biliary tubes. Mr. Brodies tied the duct coming from the liver, in a living animal, which he says stopped the process of chylification: the experiment was repeated by Mr. Magendie, without producing the same effect. It is, however, certain that no chyliferous vessels can be discovered in the small intestine above the place where the ducts from the pancreas and liver enter. The chyle that is

taken up by the lacteals, is conveyed through vessels appropriated to the purpose, into the blood. The course which it takes, and the agents by which it is effected, will be described when we speak of absorption. Before doing this, however, it will be proper to give some account of the circulation of the blood, the circulating apparatus, and the nature of the blood itself.

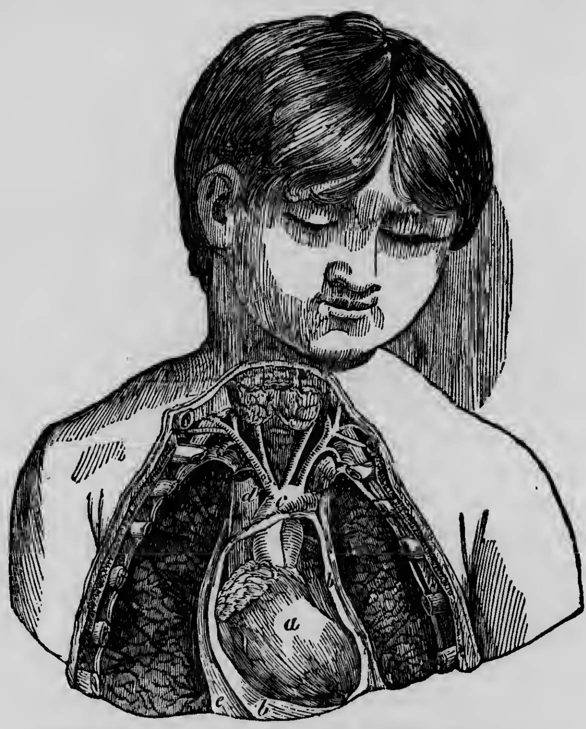
CHAPTER II.

OF THE CIRCULATION OF THE BLOOD.

THE agents by which the circulation of the blood is carried on, are the heart, the arteries, and the veins. The heart is a hollow organ, of an irregular conical shape, and of a muscular and fibrous structure. It is situated in the anterior part of the cavity of the chest, inclining towards the left side. It rests on the diaphragm, the muscle which separates the chest from the abdomen, and it is supported at its base, which is uppermost, by the large blood-vessels with which it is connected. It is enclosed in a strong bag, called pericardium, which is attached below to the diaphragm, and above to the great arteries and veins, which go out of and come into it. The heart is covered on its exterior by a serous membrane, and the pericardium is lined with the same. Within the pericardium, there is usually found after death a small quantity of serous fluid, varying from an eighth to half an ounce, which is supposed to be in the form of vapor during life.

The heart in man is a double organ, and there is no direct communication between the two sides after birth. It is by one of these sides, that the circulation is carried on in the lungs, and by the other throughout

the rest of the body. They are usually called the right and left sides, though it would be more proper to call them anterior and posterior, or designate them by

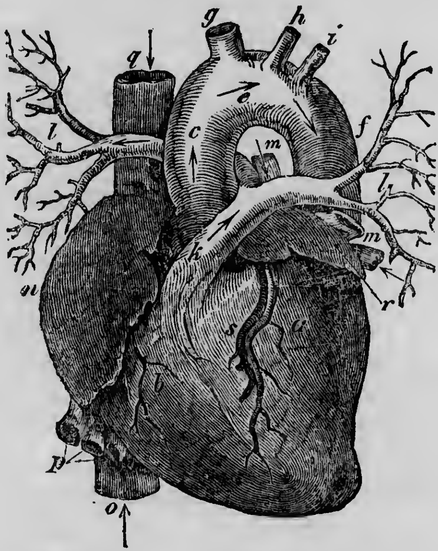


The cavity of the chest laid open, to show the heart and lungs. *a* The heart. *b b* The pericardium, cut open. *c* The aorta, the great artery of the left side, that distributes the blood to all parts of the body. *d* The great vein, called the descending vena cava, which, with the ascending, brings the blood to the right auricle. *e* The pleura or membrane that covers the lungs.

the names of the parts with whose circulation they are connected. The error arose with the ancients, whose prejudices did not allow of human dissection, and who

obtained their ideas of the circulating organs by the dissection of monkies, in whom the heart is somewhat differently placed than in man.

The anterior or right side of the heart, as it is called, sends the blood to the lungs; the posterior, or left side,



a The left ventricle. *b* The right ventricle. *c e f* The aorta, the great artery that goes off from the left ventricle. *g h i* The arteries that are sent from the arch of the aorta. *k* The pulmonary artery, that goes from the right ventricle to the lungs. *l l* Branches of the pulmonary artery, going to the two sides of the lungs. *m m* The pulmonary veins, which bring the blood back from the lungs to the left side of the heart. *n* The right auricle. *o* The ascending vena cava. *q* The descending: these two meet, and by their union, form the right auricle. *p* The veins from the liver, spleen and bowels. *s* The left coronary artery; one of the arteries which nourish the heart.

sends it to the rest of the body. Each side of the heart is divided into two parts; the uppermost, which is a membranous bag, is called, from its resemblance to

an ear, auricle. Though membranous, it is not entirely destitute of muscular fibres, and is consequently possessed of some contractile powers. The auricle communicates directly with the lower part, which is much thicker, and composed chiefly of strong muscular fibres: this is called the ventricle.

In the human heart, therefore, there are four cavities, two auricles, and two ventricles. The auricles are situated at the upper part, and communicate freely with the ventricles. The auricle and ventricle of one side are separated from those of the other by a septum, through which there is no communication in a healthy individual after birth; before that the blood passes from one auricle to the other. The right or anterior auricle is somewhat larger than the left, being in the proportion of about seven to five. The cavities of the two ventricles are nearly of a size, but the parietes or walls of the left are much thicker and more powerful than those of the right. The auricles receive the blood from the veins, and transmit it immediately into the ventricles: when the blood, thus transmitted, enters the right ventricle from the auricle, the ventricle contracts and throws its contents through a system of arteries, destined for the purpose, to the lungs. The blood is prevented from returning to the auricle by valves which open towards the ventricle. A similar arrangement exists on the left or posterior side of the heart; the blood passes from the left auricle to the left ventricle, and is thence sent to all parts of the body.

The vessels which convey the blood from the heart, are called arteries. This name was given to them by

the ancients from a belief that they contained air. They are generally described as having two coats, the outer one being almost entirely composed of cellular membrane, is called the cellular coat, and the inner one, which is much firmer and very smooth, partakes of the nature of the tendons, and is evidently of a fibrous structure. Between these two coats, there are some transverse fibres, which seem to be of a muscular character, and which have sometimes been called the muscular coat. These fibres give the arteries a contractile power.

At the mouths of the two great arteries that go off from the heart, there are three valves in each, which prevent the blood that enters the arteries, from returning to the heart. There are no other valves found in any part of the arterial system.

The arteries are strong elastic tubes, of somewhat of a conical shape, and of a white color. Their firmness and elasticity have been made very apparent in some cases of severe injury. Accidents not unfrequently occur, in which the bones of a limb will be broken, the muscles or flesh torn through, and yet the artery, though stretched to a great degree, remains whole and apparently uninjured.

The veins are the vessels by which the blood is conveyed to the heart. They differ from the arteries in being thinner and more delicate, of a less white color, and possessing but few, if any, of the transverse muscular fibres. There is another difference too, of some importance, which is, that many of the veins, particularly in the extremities, are furnished with valves.

It must be apparent, even to a casual observer of the vital phenomena, that the blood is in perpetual motion during life. This was familiarly known to the ancients, but they were wholly ignorant of the course which the blood took, and the means by which its motion was kept up. They believed that the arteries contained air, and that the blood was to be found only in the veins. These opinions, with but slight variation, were prevalent till the seventeenth century. The discovery of the circulation of the blood, was made by Dr. William Harvey, an English physician, in the year 1620, though he did not make it public till eight years after. Servetus, better known as a theologian, and one or two others before Harvey's time, made some steps towards this important discovery, but not enough to diminish in the least degree, the glory to which the discoverer of a fact of such incalculable importance is justly entitled. When he first made his discovery public, he adduced in support of it such facts and arguments, that it seems almost incredible at the present day that it was not at once acknowledged. But so far from this being the case, that it was at the time regarded with distrust by individuals of all descriptions, his professional business was sensibly diminished by it, and it has been asserted, that there was not a physician, who was forty years of age, at the period of its promulgation, who ever became a convert to the doctrine. Notwithstanding all these discouraging circumstances, Harvey lived to see the truth of his doctrine universally admitted, and to reap some of the fruits of his splendid discovery.

Though no one at the present day pretends to deny that the blood passes from the heart through the arteries

into the veins, and is returned by them to the heart again; it may still be well to notice some of the facts and arguments that have been adduced in support of it. It is but justice, however, to Harvey to observe, that his first publication on the circulation of the blood contained nearly all the proofs of the fact that have ever been adduced.

If the chest of a cold-blooded animal, (for animals of this class are the most tenacious of life, and can consequently bear such an experiment better than warm-blooded animals,) be opened, the heart will be seen alternately to dilate and contract. It then remains for an instant apparently at rest, the dilatation again commences, and when it has arrived at a certain point, contraction takes place. When the heart contracts to expel the blood, it rises up, as it were, on its base, and its apex strikes against the ribs, which produces what is called the beating of the heart. This has been supposed to be owing to the dilatation of the heart; but it is not so, — it is produced by its contraction; and this fact was known to Harvey.

The valvular structure of the circulating system is a strong fact in favor of the received opinion as to the course of the blood. The valves situated between the auricles and the ventricles, allow the blood to pass freely from the former into the latter, but they effectually prevent the blood from going from the ventricle to the auricle. The valves placed at the commencement of the arteries that go off from the heart, permit the blood to enter the arteries from the ventricles, but completely prevent it from returning to the heart. The

same may be said of the valvular structure of the veins; it allows the blood to go towards the heart, but not in the other direction. These are facts that are familiar to every anatomist.

The mode in which the common operation of bleeding from a vein, either in the arm or leg, is performed, is a convincing proof of the circulation of the blood. A ligature is placed around the arm or leg above the point at which the vein is to be opened. The blood is returning through it towards the heart, its passage is of course interrupted; the vein consequently swells, because the artery, which is deeper seated, is not compressed, and continues to carry the blood to it, and if the vein is then opened below the ligature, the blood flows freely; but no blood is obtained if an opening be made above the ligature. It sometimes happens to an inexperienced operator, to apply the ligature so tight, as to compress the artery; the consequence is, that after the vein is emptied, no more blood flows; but if the ligature be removed, and reapplied less tightly, the vein will bleed again.

The manner in which the bleeding from the vessels that are divided in surgical operations is stopped, is another proof of the circulation of the blood. In the amputation of an extremity, for example, that is, the removal of an arm or a leg, the surgeon ties only the arteries. These carry the blood from the heart to all parts of the body, and the patient would soon bleed to death, unless some means were adopted to prevent it. The veins, however, which carry the blood back to the heart, though they are usually as large as the arteries, do not bleed, and of course are not tied.

It has been said, that the circulation through the arteries and the veins, may be seen by a microscope in some delicate parts, as in the web of a frog's foot. Malpighi first made this observation, and it has been so frequently repeated, that no doubt now remains on the subject. It may therefore be considered an additional proof of the circulation of the blood. Microscopical observations, however, when adduced to maintain any theory in physiology, and unsupported by other evidence should be received with caution, as the observers not unfrequently see precisely what they wish.

With a knowledge of such facts as these, it is impossible to resist the conclusion, that the blood passes from the heart through the arteries into the veins, and is returned by them again to the heart. The chyle, as has been before stated, when speaking of digestion, which is formed in the duodenum, is taken up by a set of absorbent vessels, whose mouths open in that intestine, and which are called lacteals, and is thence conveyed into the blood. These absorbents unite in a common trunk, called the thoracic duct, which pours its contents into a vein, situated under the collar bone. This vein soon empties its blood into a large vein, which receives all the blood coming from the parts above the heart; another large vein receives all that which comes from the parts situated below that organ, and these two veins, which bring the blood from every part of the body except the lungs, pour their contents into the right, or anterior auricle. From the auricle the blood is immediately conveyed into the ventricle, probably by means of a slight contraction of those muscular fibres,

with which it is known the auricle is furnished. As soon as it enters the ventricle, a powerful contraction takes place, and the blood is driven with great force through the pulmonary artery into the lungs. When this contraction is made a portion of the blood would be forced back into the auricle, were it not for three valves called tricuspid valves, which are situated between the auricle and ventricle. The blood might also flow back from the artery as the contraction ceases, if there were not some mechanical means to prevent it, and these consist in three valves situated at the entrance of the artery, called semilunar valves.

Between the termination of the arteries and the commencement of the veins, there exists not only in the lungs, but throughout the body, an intermediate set of vessels, which, from their minute size, are called capillaries. It is in them that the vital functions of the circulating system are carried on, and it is in the capillaries of the lungs that that peculiar change takes place in the blood, which is effected by respiration, and which will be particularly described in treating of that function. The circulation of the capillary vessels is independent of the heart, but is carried on by the muscular power of the vessels themselves. The blood having passed through the capillary system of the lungs, and having undergone a remarkable change in its properties and color, being converted from dark purple to bright scarlet, is carried by the veins to the left or posterior auricle of the heart. It then goes, as on the other side, into the ventricle. This ventricle, which is far more powerful than the other immediately contracts, and throws the

blood into a great artery, which distributes it throughout the body. A similar arrangement of valves is found in this side of the heart, as has been described as existing in the other. There are three valves between the posterior or left auricle and ventricle, called mitral valves; and at the commencement of the aorta, or great artery, which goes off from this side of the heart, there are three more which are called semilunar valves. The first set of these valves prevents the blood from returning to the auricle when the ventricle contracts, and the second prevents that which is thrown into the artery from re-entering the ventricle, when its contraction has ceased.

The blood, having passed through the arterial and capillary systems, enters the veins, and is carried by them to the anterior or right auricle of the heart, to go through again the course which has just been described.

It was before observed, that in man, the heart is a double organ, and it now appears that there are two distinct circulations, in some degree independent of each other. One of these, is that of the lungs, the other is that of the general system. The objects effected by each are different, and will be spoken of hereafter.

There has been much diversity of opinion among physiologists upon the question, whether the blood is carried through the arteries by the action of the heart alone, the arteries being merely inert canals, or whether the arteries themselves act upon their contents, and thus aid in the circulation of the blood. The point may be still considered unsettled. A great majority, however, incline to the opinion that the arteries are not

wholly inactive. They are known, especially the smaller branches, to possess muscular fibres, and of course they must have contractile power; it has been ascertained in some cases, where an artery has been divided in a living animal, and has not been tied, that the divided artery has contracted to a considerable extent.

If the finger be placed with a moderate degree of force over some of the arteries, a pulsation will be felt, which corresponds with the contractions of the posterior or left ventricle of the heart; this is called the pulse. It was supposed, till recently, to be owing to a dilatation of the artery, produced by the entrance of the blood into it. It was doubted by Bichat, whether any dilatation of the artery took place, and Dr. Parry satisfied himself by repeated observations that it does not, and ascribes the pulse to the 'impulse of distention' given by the contraction of the ventricle. A more recent observer, however, Dr. Hastings, maintains that in repeating Dr. Parry's experiments, he noticed a dilatation of the arteries. It is perhaps right, therefore, to attribute the pulse to the combined action of these two causes, viz. the impulse of distention imparted by the ventricle, and a slight degree of dilatation of the artery itself.

The blood circulates through the capillary system by the action of the capillaries alone; they do not feel the influence of the heart. In the pulmonary circulation, it is in the capillaries that the change in the blood which is effected by the air is wrought; and in the circulation of the general system, it is in them that the

process of nutrition goes on. The blood having parted with such portions of it as are necessary to support the system, the remainder is conveyed by the capillary vessels to the veins, with a change in its color and properties.

There is some diifference of opinion as to the means by which the blood is carried through the veins. Harvey supposed that it was done by the action of the heart, which contracted with sufficient power to send this fluid through its whole course. This hypothesis has no advocates at the present day. It is believed by physiologists, that the circulation in the capillary ves sels is independent of the action of the heart, and if this be true, this organ can of course have no power over the circulation in the veins.

Bichat thought that the venous circulation was carried on by means of the capillaries; that these vessels not only circulated the blood which they contained and conveyed it into the veins, but that they also carried it through these vessels to the right side of the heart. He considered them, in fact, as an agent of impulse, placed on the circumference, which corresponded to the agent of impulse, the heart, which is placed at the centre.

Other physiologists have supposed that the blood was circulated through the veins on the common principle of hydraulics, that a fluid contained in tubes will rise to the height of its source. This explanation is too mechanical to be admitted to its full extent; though there can be but little doubt that the gravity of the blood must exert some influence upon its circulation through the veins, and it is probable, that those vessels themselves take but little, if any, active part in it.

Some of those who have admitted the influence of the two last causes, have attributed something also to muscular contraction, which would act with greater power in some parts of the body than in others. When the muscles contract, they press upon the veins, and thus aid the blood in its passage towards the heart. It cannot go in the other direction, particularly in the extremities, on account of the numerous valves that exist in the veins. The contraction of the muscles, so far as it has any influence on the arteries, tends to retard the circulation; it diminishes the diameter of the artery, and consequently offers an additional resistance to the action of the heart. But little effect of this kind, however, is produced; partly because the coats of the arteries are much firmer than those of the veins, and are not, therefore, so easily acted upon; and partly because the arteries are so situated that they are less subject to the action of the muscles than the veins.

When the situation of the veins is considered being placed some above, others beneath, and others again passing through the muscles, it is easy to believe that their coats, destitute in great measure of muscular fibres, would yield to the muscles in a state of contraction; and when they are thus compressed, it is obvious from their valvular structure that the blood must be sent towards the heart.

To the agents already enumerated as the supposed causes of the venous circulation, two others have been added, which are sometimes called the suction powers of the lungs and heart. It is believed, by those who attribute any influence to these causes, that in inspiration

or the act of drawing the air into the lungs, the blood is also drawn into the right side of the heart, by the approach as it were of a vacuum, produced by an enlargement of the cavity of the chest.

The suction power of the heart has also received the name of derivation. When the ventricles have contracted and sent out the blood which they contained, they relax, and consequently become enlarged, and a vacuum would take place, if the blood did not flow in from the auricles.

It may then be said, that the blood is carried through the arteries chiefly by the action of the heart, aided in a slight degree, perhaps, by the elasticity and contractile power, which reside in the arterial coats; that the circulation through the capillary system is effected entirely by the capillaries themselves, and that the blood is thrown by them into the veins, and that it is carried through them, probably by the combined action of a part or the whole of the causes just pointed out.

It has been estimated that two ounces of blood are thrown out of the heart at each contraction of the ventricle, and that this fluid constitutes about one-fifth part of the weight of the body. It follows, therefore, that the quantity of the blood is different in different individuals according to the size of the body, varying in healthy adults from twenty-five to thirty-five pounds, and in some cases it is even more than this. Now suppose that there are seventy pulsations or contractions of the heart in a minute, the whole blood of the body, even allowing it to amount to thirty-five pounds, must pass through that organ in less than three minutes. And so impor-

tant is the action of the heart, that if it be suspended for a moment, death ensues. That this organ, constructed apparently of such frail materials, and exposed to such great irregularity in its action, should, during a long life, perform its functions so perfectly, is calculated to give us the most exalted ideas of the power and wisdom of the Creator of our bodies.

Of the Blood.

The blood is an adhesive fluid from which all the other parts of the body are formed. It is contained in the heart, the arteries, the veins, and the capillary system. When drawn from the body, it soon separates into two parts, the one liquid, and the other solid, which floats in it; the liquid is called serum, and the solid, crassamentum. This change is known by the name of the coagulation of the blood, and takes place on an average in about seven minutes after it is drawn from the vessels. The time, however, varies, partly from the manner in which the blood is drawn, and more from the temperature of the atmosphere in which the operation is performed; it coagulates quicker in a high temperature than in a low one.

The temperature of the blood may be considered to be about one hundred degrees of Fahrenheit's thermometer. The blood of the veins is not perhaps quite so high as this, while that of the arteries is somewhat higher.

It is not easy to determine the exact proportion of the serum and the crassamentum, because some of the

former adheres so closely to the latter, that it cannot be separated from it. It is generally supposed, that the weight of the serum is three times greater than that of the crassamentum.

When the crassamentum is taken out of the serum, it is found to be a soft solid, of sufficient consistence to be cut with a knife. If washed for some time in water, it loses its red color, showing that the red particles were only united to it by mechanical mixture. The solid thus obtained is of a dingy white color, elastic, of considerable firmness and tenacity, and of a fibrous structure. It is known by the name of fibrin. It is the same substance which is sometimes called by the different names of coagulable lymph, fibre of the blood, gluten, and adhesive matter. It constitutes the basis of the muscles or flesh. It is the substance which is poured out on all the serous membranes, when in a state of inflammation; and it is the means by which the union is effected in wounds. When any of the soft parts of the body are divided, fibrin is immediately effused from the cut ends of the blood-vessels, and thus glues, as it were, the wound together. This fibrin afterwards becomes organized, blood-vessels shoot through it, and the part again resumes its healthy state.

The other constituent of the crassamentum is known by the name of the red globules. These substances have afforded fruitful topics for conjecture and physiologists have indulged in the wildest speculations concerning them. They early attracted attention, and when microscopical observations first became in fashion in science, they were subjected to very minute

and faithful examination. The result was the formation of several extravagant hypotheses, to which no importance is attached at the present day.

It is impossible to obtain the red globules in a detached state, so as to subject them to any thorough and minute investigation; and this circumstance alone, will probably be sufficient to prevent us from knowing much more of them than is at present known. Berzelius, the celebrated Swedish chemist, is one of the latest, who has paid much attention to the subject. The conclusions to which he has arrived, and which no one seems disposed to controvert, are, that the red globules do not materially differ from the other parts of the blood except in the color, and the fact that a certain quantity of the red oxide of iron is found in their ashes after combustion.

Much diversity of opinion still prevails as to the size and form of the red globules. Some recent observers consider them to be about one five thousandth part of an inch in diameter, and to be of a flattened shape, somewhat in the form of an almond, instead of being spherical, as they had formerly been supposed to be.

The color of the blood is thought to be owing to the iron which it contains: this has been denied by some, but the notion is certainly favored by a large majority of the chemists of the present day. Though the existence of iron in the globules of the blood has been clearly proved, it is not known in what state it exists in them.

Of the Serum.

The serum is that part of the blood which remains fluid when spontaneous coagulation takes place. It is a transparent liquid, of a pale straw color, of a saline taste, and of a specific gravity somewhat greater than that of water. It has evident alkaline properties, as it converts vegetable blue colors to green.

The coagulation of serum by heat is, however, its most remarkable property. When exposed to a temperature of 160 degrees of Fahrenheit's thermometer, it is converted into a white opaque solid, of great consistence. In this state, it perfectly resembles the white of an egg when boiled, and hence the name of albumen has been given to it. The serum can be coagulated by other substances besides heat; such as alcohol, the mineral acids, and tan.

Though the whole serum appears to be converted into a solid substance by heat, yet if the albumen be cut into slices and placed in the mouth of a funnel, a few drops issue from it, and these have been called serosity.

Serosity, or that part of the serum which remains fluid, after coagulation by heat has taken place, is found in small quantity only. It is obtained with so much difficulty separate from the serum, that it has not, till recently, been recognized as a distinct constituent of the blood. Some French chemists asserted that it contained jelly, though it has since been proved that it does not, and that this substance is not contained in the blood; it is still known rather by its negative than its positive

properties. It certainly has one property, which distinguishes it from all the other constituents of the blood, and that is, its power of resisting all means that have hitherto been employed to coagulate it. Serosity is found to be much more abundant in the blood of old animals than in that of young; and it forms what is called the red gravy in roasted beef and mutton.

The only remaining substances that exist in the blood, are salts of various kinds. A thousand grains of serum were found to contain nine grains of salt; six of these were common salt, muriate of soda, and the remainder was made up of the muriate of potash, the subcarbonate of soda, and the phosphates of lime, iron, and magnesia.

It appears then that the blood, when drawn from the body under ordinary circumstances, soon coagulates spontaneously; a part of it only becoming solid, and the rest, much the larger portion, remaining fluid. The solid is called crassamentum, and the fluid serum. The crassamentum is composed of fibrin and red globules; the latter of which subside towards the lower part of the crassamentum during the process of coagulation, especially if the blood coagulates slowly.

The serum is composed of albumen, which is coagulable by heat, mineral acids, alcohol, tan, &c.; and serosity, which is an uncoagulable fluid, water, and various salts.

All parts of the body, as was before remarked, are formed from the blood, however dissimilar they may be in appearance, structure, and properties. From it is secreted all the solids as well as the fluids; and some

of the solids seem to possess properties very unlike those of the blood, as the hair, the nails and the bones. It is the blood that repairs the waste that is going on in our organs, and it also gives a stimulus to the brain and nervous system, without which they would be incapable of action. If the ordinary supply that is sent to the brain be cut off, its functions are immediately suspended; and if blood be carried there which has not undergone the changes, which are effected in it by the lungs, its functions are destroyed. What these changes are, will be pointed out, when treating of respiration, of which we shall next speak.

CHAPTER III.

OF RESPIRATION.

Respiration is that process by which air is taken into the lungs and expelled from them. The act by which the air is taken in, is called inspiration, and that by which it is thrown out is called expiration.

The wind-pipe and the lungs are, strictly speaking, the only respiratory organs. But as the purpose of respiration is to produce a remarkable change in the blood, it has been usual to include the blood-vessels of the lungs among these organs. The respiratory apparatus, however, embraces all those agents which perform any part in the mechanical process of respiration.

The wind-pipe is a tube composed of cartilaginous rings, extending from the mouth into the lungs. It is situated in front of the passage to the stomach, and at its upper extremity there is a valve, already noticed, which prevents the entrance of foreign substances into it. The rings of which it is composed, are not cartilaginous in their whole circumference; they are membranous in the part where the wind-pipe is joined to the œsophagus.

As soon as the wind-pipe reaches the lungs, it divides into two branches, one going to each side; these are

immediately subdivided into numerous smaller branches, which finally terminate in air cells. After a few of the first subdivisions, the wind-pipe ceases to be cartilaginous; all the small branches are membranous.

The lungs occupy a large part of the cavity of the chest. They are divided into three parts, or lobes, on the right side, and two on the left. They are composed almost entirely of air-tubes, and air-cells, and blood-vessels; these, with the cellular membrane that connects them, constitute in fact, their whole substance. They are so vascular, that after air has once been admitted into them, they are specifically lighter than water. A knowledge of this fact has led to a mode of determining whether infants, supposed to have been murdered, were born alive or not. If the lungs would float in water, it was decided that the children must have breathed, and of course have been born alive; if on the contrary they sunk, it was considered a proof that they had never breathed.

This is, however, somewhat of a fallacious test; for the lungs will float in water, even though the air may never have been admitted into them, as soon as the putrefactive process has commenced.

The lungs in the inferior animals are known by the popular name of lights.

The nerves that are sent to these organs, arise in part from a nerve that originates in the brain, the eighth pair, and in part from the sympathetic nerve.

The air-tubes and air-cells are lined by a mucous membrane, and the lungs are covered on the exterior by a serous membrane, called the pleura, which is the

seat of the disease known by the name of pleurisy. This membrane not only covers the lungs on the exterior, but lines also the chest, and is constantly lubricated in health, by a serous fluid which is exhaled from it.

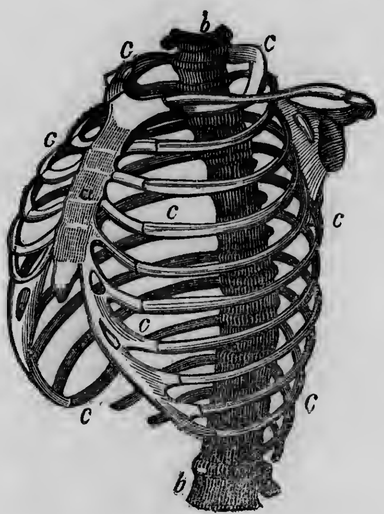
To give a perfectly correct notion of the process of respiration, it must be considered under three points of view; 1st, as a mechanical process; 2d, as a chemical one; and 3d, as a physiological or vital process.

Under the first head must be considered the mechanism of respiration, that is the mechanical apparatus by which it is effected.

Under the second will be noticed the change that is produced in the air by this process; and under the third will be considered the changes wrought in the blood, and the consequent effect on the whole system.

1st. The mechanical process of respiration consists in inspiring and expiring atmospheric air. The apparatus by which this is accomplished is somewhat complex. The chest or thorax, as it is called, in which the lungs are situated, is of a conical shape, with its apex uppermost. The walls, or parietes of the chest, are partly bony and partly muscular. The breast bone forms the front wall, and the spine or back bone constitutes the posterior one. To this are attached twelve ribs on each side; the seven uppermost are called true ribs, because they unite by distinct cartilages to the breast bone; and the five lower ones are called false, because some of them unite in a common cartilage before they are joined to the breast bone, and the others are not connected with it at all. The ribs form the lateral and superior walls of the cavity of the thorax. The inferior

wall is formed by the diaphragm, a muscle of great power which separates the cavity of the thorax from the cavity of the abdomen. It is attached at its circumference to the lower part of the chest, and when in



TRUNK OF THE HUMAN SKELETON. *a* The sternum or breast bone, *b b* The spine. *c c c c* The ribs.

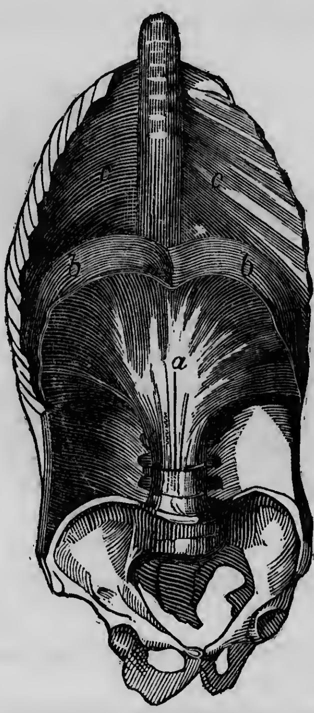
a state of relaxation, the centre is considerably elevated above the circumference.

Between the ribs are situated numerous small muscles, which are called intercostals, from their situation, and which are supposed to elevate the ribs.

There are other muscles which may be considered respiratory muscles, as they have the power of contributing to the enlargement of the cavity of the chest.

The lungs are in contact with the inner side of the

cavity of the chest. In inspiration this cavity is enlarged, sometimes in one direction principally, and at others in all.



The DIAPHRAGM during expiration. *a* Its tendinous centre. *b b* Its fleshy sides. *c c* The lateral cavities of the chest in which the lungs lie.

Ordinary inspiration may be accomplished by the action of the diaphragm alone. The contraction of this muscle necessarily depresses its centre, which was before elevated towards the lungs. The instant this takes

place, the air rushes into the lungs through the windpipe, and thus prevents a vacuum, which would otherwise be produced between the chest and the lungs, In every inspiration, the ribs are somewhat raised,

The LUNGS of Man. *a* The heart. *b b* The Lungs. *c c* The Diaphragm.

though ordinarily in a very slight and almost imperceptible degree.

In a full inspiration, there is an evident elevation of the ribs, and in a forced inspiration, this elevation is much greater ; the cavity of the chest being in both cases much more enlarged than in an ordinary inspiration.

This enlargement of the chest by the elevation of the ribs, is owing to the oblique direction in which the

ribs are placed ; so that when they are raised up, they are also turned outwards, and the cavity of the chest is consequently much enlarged.

The ribs are elevated in inspiration by the contraction of certain muscles. It was the opinion of Haller that this elevation was produced by the intercostal muscles, those muscles that are situated between the ribs. He supposed that the first rib was immoveable, and served as a fixed point, and that the contraction of the muscles that arose from it, raised the next rib, and that in this way all the ribs were elevated. This opinion has been generally adopted by physiologists till very recently, when it has been called in question by the celebrated Magendie of Paris. He denies that the first rib is immoveable, and appeals to every one's experience for the correctness of his opinion, and consequently denies that the intercostals are the agents by which the ribs are elevated. This effect, he says, is produced by those muscles which arise from the head, the spine and the superior extremities, and which are inserted into the chest. His opinion as to the mode in which inspiration takes place, differs from the one that is generally received, merely as to the particular muscles that elevate the ribs : the effect he admits to be the same, though produced by different agents.

Expiration, by which the air is expelled from the chest, is merely the reverse of inspiration. It has, like it, three degrees, the ordinary, the full, and the forced. The relaxation of the inspiratory muscles, and a slight contraction of the expiratory ones, enable the ribs and the breast bone to resume their ordinary situation. In

forced expiration, however, the cavity of the chest is still farther diminished, by a powerful contraction of the expiratory muscles.

It is not easy to decide how much air is taken into the lungs at each inspiration. It is obvious that the quantity must be very different in different individuals, from the great difference that is known to exist in the size of the chest. The quantity too must differ in the different kinds of inspiration, much more being taken in in a forced inspiration than in an ordinary one. But, after allowing for these differences, physiologists have been unable to determine, with any degree of accuracy, the quantity of air taken into the lungs at each ordinary inspiration by an individual of the common size. The experiments, however, in which the most confidence is placed, fix the quantity at forty cubic inches for an ordinary inspiration ; it has also been shown that one hundred and seventy cubic inches can be expelled from the lungs by a forcible expiration, and that one hundred and twenty cubic inches will still remain in them; so that the lungs may be considered as containing two hundred and ninety cubic inches in their quiescent state: to this amount must be added sixty inches for an ordinary inspiration, which will make the lungs contain three hundred and thirty inches in their distended state. Assuming these calculations to be correct, it follows that about one eighth part of the air contained in the lungs is changed in each inspiration.

The number of inspirations in a minute varies somewhat in different individuals, the smallest number taken in health by an adult male is not less than fourteen, and

they rarely exceed twenty-five. Eighteen is considered as the average number. Children and females breathe more rapidly than men; but even allowing that eighteen inspirations are made in a minute, it makes the number taken in twenty-four hours amount to more than twenty-five thousand, and the quantity of air respired in that time exceeds one million cubic inches.

2d. Respiration may be considered as a chemical process, if we regard the changes it produces in the air which is taken into the lungs. Atmospheric air is a transparent, compound fluid, elastic and compressible. It is composed of oxygen and azote, in the proportion of twenty-one parts of the former to seventy-eight of the latter, and one part of carbonic acid gas, or fixed air. Oxygen, or vital air, as it is sometimes called, because life cannot exist without it, though it is unfit for respiration unless combined with other gases, is somewhat heavier than atmospheric air. It takes its name from two Greek words, which mean the generator of acid, because it was supposed till recently to be the sole acidifying principle. It is a simple substance, and enters freely into combination with a great variety of other substances. Combustion cannot take place without it.

Azote, or nitrogen, is so called, because life cannot be supported by it. It always exists in a gaseous state; it is insoluble in water, and not so heavy as atmospheric air. A lighted candle plunged into it is immediately extinguished; it forms the basis of nitric acid, enters largely into the composition of all animal, and some vegetable substances. Like oxygen, it is a simple sub-

stance, and forms, when combined with it in different proportions, compounds of very dissimilar characters; such as atmospheric air, nitric acid, and nitrous oxyd, or exhilarating gas. It does not possess any positive deleterious properties, and it destroys life, when it is respired alone, merely by its negative ones.

Carbonic acid gas, or fixed air, which constitutes only one part in the hundred of atmospheric air, is not a simple substance, but is composed of carbon and oxygen. It is called an acid, because it has the property, though in a slight degree, which is peculiar to acids, of turning vegetable blues to red. It is soluble in water, and much heavier than atmospheric air. It is incapable of supporting respiration or combustion. A lighted taper plunged into it is immediately extinguished; and if an animal attempt to breathe it but for an instant, he is deprived of the appearance of life; and unless he be immediately furnished with atmospheric air, he cannot be resuscitated. It is this gas which is found in the bottoms of wells and cisterns, and which renders them so unsafe to those who enter them without proper precaution.

While it is certain that carbonic acid gas possesses deleterious properties of a positive character, that render it unfit for respiration, even if it could be taken into the lungs, it is productive of very agreeable effects, when conveyed into the stomach. When dissolved in water, it imparts to it a pleasant, acidulated taste. It forms the sparkling property of mineral waters, both natural and artificial; and in this way it is freely drank, without any injurious consequences: on the contrary, its effects are oftentimes salutary.

The air that we breathe, it thus appears, is a compound fluid, consisting of twenty-one parts of oxygen, seventy-eight parts of azote, and one part of carbonic acid gas. It is next to be seen what changes are produced in this fluid by respiration.

The ancients knew nothing of the changes effected in the air by the lungs. Their observation, to be sure, taught them, that respiration was essential to life; but they attributed this to the supposed effects which this process had on the circulation of the blood. It did not of course escape them, that the air thrown out of the lungs is warmer and more moist than when taken into them; but they were not aware that any other change was produced in it. This is not to be considered remarkable, when we recollect, that they were ignorant of the compound nature of atmospheric air.

The first approach towards the truth was made by Mayow, an English philosopher, in the year 1674. He stated that the air was a compound fluid; that one of its constituents was essential to life and combustion, and that this principle combined with the blood in its passage through the lungs. But he went no further; he knew nothing of the precise composition of atmospheric air, nor of the change which was effected in it, and in the blood, by respiration. His opinions were received with but little favor, and the ancient doctrine continued to prevail for many years after his time.

Dr. Black, in the year 1757, made known the important fact, that carbonic acid is produced in the lungs by respiration; and a few years afterwards, Dr. Priestly discovered the nature and properties of oxygen gas.

He made many experiments on the subject of respiration, and though he did not perfectly explain the changes produced by it in the air taken into the lungs, his followers are indebted to his discoveries for the additional light which they have been able to shed on the subject. Many learned men have since this period labored to elucidate this obscure point in physiology; and though there may be a slight difference in the results to which they have arrived, there is sufficient agreement among them for all practical purposes.

The volume of air thrown out of the lungs, is somewhat less than that which is taken into them. It is not easy to estimate with precision this loss, as it varies under different circumstances; the results of the experiments that have been made to settle this point, have differed considerably, there being in some cases no apparent loss, while in others it was very evident. Some of the best physiologists of the present day, however, have fixed the amount lost at one eightieth part of the volume taken into the lungs; that is, half a cubic inch at each inspiration.

The quantity of azote or nitrogen is nearly the same under ordinary circumstances, in expired air as in the air which is inspired. Some experimenters have recently asserted that there is a loss of azote in respiration; but the amount of the loss is small, nor does it appear to be a uniform effect of respiration. It is safe, therefore to conclude, that if there be any loss of azote, it is trifling in amount, as this loss frequently has not been detected in very skilful and well-executed experiments.

The quantity of oxygen is diminished by respiration, and that of carbonic acid gas is increased. Expired air, instead of containing twenty-one parts of oxygen, like atmospheric air, has but eighteen parts, and contains four parts of carbonic acid gas, instead of one. Some physiologists are of opinion that all the oxygen that has disappeared, may be accounted for by the carbonic acid gas that is formed, while others believe that a portion has united with the blood. This point may perhaps be considered as still unsettled. We shall say more of it when treating of the changes produced in the blood by respiration.

3d. The next point of view in which the important process of respiration is to be considered, is as to the effects which it produces on the blood that is sent to the lungs. It has been before explained that the blood, which is derived from digestion, and that which is returned by the veins from all parts of the body, is carried to the right side of the heart. It is of a dark color, and unfit for the purposes of life. It is sent by the contraction of the right ventricle to the lungs ; it passes through numberless vessels of the smallest size, and is carried to the left side of the heart, of a bright scarlet color. How is this effected ? We have seen above that the quantity of carbonic acid is greater in expired, than in atmospheric air. But the oxygen contained in the carbonic acid gas, does not account for all the oxygen that is lost. Some have supposed that a portion of it unites with hydrogen, and thus forms the watery vapor that is thrown off from the lungs. This is not, however, the prevailing opinion. The fact seems to be, that in respiration, both the air and the blood

part with something, and receive something from each other. The air loses a portion of its oxygen, a part of which goes to the formation of the carbonic acid, and the remainder unites with the blood ; the blood also parts with some of its carbon, which unites with the oxygen taken into the lungs, and is then thrown out in the form of carbonic acid ; and another part of the oxygen is absorbed by the blood. Thus it appears that the blood parts with a portion of its carbon, and at the same time gains some oxygen.

This change in the blood in respiration, has been called the oxygenation of the blood, by those who explained it, on the supposition, that oxygen united with the blood in its passage through the lungs. It has also been called the decarbonization of the blood, by those, physiologists who believe that the change is produced by the discharge of carbon. The truth seems to be, that the blood is both oxygenated and decarbonized by respiration; that is, that a portion of the oxygen taken into the lungs unites with it, and at the same time the blood throws off carbon in a volatile state, which unites with another portion of oxygen, while the air, at the same time, loses some oxygen and receives some carbon, and thus forms carbonic acid gas.

It is certain, that if purple blood, out of the body, be exposed to the contact of oxygen gas or atmospheric air, it will become of a bright scarlet color. And on the contrary, blood of a scarlet color becomes purple when in contact with hydrogen, nitrogen, or carbonic acid gas. It seems also to be well settled, that if any part of the azote or nitrogen of the air be absorbed by the blood, it is given out again, as there is no percepti-

ble difference between the quantity that is expired, and that which is inspired. It is admitted too that no hydrogen is thrown out from the blood, but that the aqueous vapor which is discharged from the lungs is an exhalation of the watery or serous part of the blood. There can be but little doubt, that the blood absorbs, during respiration, more oxygen than is necessary to form the carbonic acid that is expired, and that the remainder unites with the blood, and contributes to the remarkable change which takes place in the appearance and properties of this fluid in its passage through the lungs.

To whatever circumstance this change may be owing, it is certain, that it is one essential to life. If it were completely suspended, even for a moment, death would follow. The black blood, or the blood of the veins, or venous blood, as it is called, cannot support the animal functions; they require the stimulus of the red arterial blood.

If respiration be suspended, the heart will for a time continue to throw the blood to the lungs; but when all the air is exhausted in these organs, so that they return purple blood to the left side of the heart, death immediately follows. This is owing, in great measure, to the circumstance that black blood is now of course thrown into the coronary arteries, the nourishing arteries of the heart; and this organ ceases to act, when not excited by arterial blood. The action of the brain, too, cannot be continued for an instant, without the stimulus of oxygenated blood, and all the organs of the body are dependent on the brain and nervous system for their power of action.

Atmospheric air is the only air which is capable of permanently supporting respiration. There are some others which are respirable, and others again which cannot enter the lungs. Oxygen, when respired, has been found highly stimulating, producing an increased action of the circulating system, and a consequent glow over the whole surface of the body. It is the opinion of Sir Humphrey Davy, that if it were breathed for any length of time, it would be productive of fatal consequences.

Nitrous oxide, or exhilarating gas, when respired, produces a great excitement of the brain and nervous system, attended for the most part with very agreeable sensations. Its effects are somewhat like those of alcohol, with this difference, that they are not so permanent, nor are they followed by a state of exhaustion.

Hydrogen and nitrogen or azote, have no positive deleterious properties, but are injurious when respired only by excluding oxygen from the lungs.

Carburetted hydrogen, which is the gas that is employed for gas lights, is positively injurious. If it be respired perfectly unadulterated, it is said to produce instant death. When mixed with atmospheric air, it produces vertigo, and loss of perception.

All the other gases are unrespirable; even carbonic acid gas cannot be taken into the wind-pipe by the most powerful voluntary efforts.

When it is recollected, that atmospheric air is alone capable of permanently supporting respiration, and that every adult individual respires about one million cubic inches in every twenty four hours; when it is borne in

mind how essential this process is to health and even life, that the functions of the body cannot be perfectly performed, if the lungs be not properly supplied, that the spirits are depressed, and the energies of the mind impaired, it must be obvious that too great care cannot be taken that the apartments in which we live, should be well ventilated, that too many individuals should not be crowded together, and thus be compelled to breathe air which has been already respired, but that the lungs should be constantly furnished, both by day and by night, with that air which can alone impart vigor to the physical and intellectual system.

There are several actions of common occurrence, that are so intimately connected with respiration, that it may be proper to speak of them in this place; such as sighing, yawning, coughing, sneezing, laughing, and hiccup.

Sighing consists in a full and long continued inspiration: its purpose, when unconnected with the state of the mind, seems to be to facilitate the passage of the blood through the vessels of the lungs.

Yawning, like sighing, consists of a full and protracted inspiration; but it differs from it in being followed by a slow expiration, and by being attended by an involuntary distension of the jaws.

Coughing is produced by a quick and powerful contraction of the diaphragm, which distends the lungs with air, and this is driven forcibly by the contraction of the abdominal muscle through the trachea, for the purpose of expelling any foreign or irritating substance that may be lodged there or in the lungs.

Sneezing resembles coughing; but it is more violent and involuntary. The irritation that produces it, is applied to the mucous membrane of the nose, and Sir Charles Bell has shown that there is a connexion by means of nerves between this part and some of the respiratory muscles.

Laughing is the effect of an inspiration succeeded by short, rapid, and imperfect expirations.

Hiccup is produced by a convulsive, rapid, and involuntary contraction of the diaphragm. In a low state of protracted disease, it is an alarming symptom, and not unfrequently precedes dissolution. There are some other actions that might be noticed, if it were necessary; but it does not seem to be, as they may be easily understood by attending to what has preceded. The *voice* and *speech* will be spoken of in another place.

CHAPTER IV.

OF ANIMAL HEAT.

Living animal bodies in health retain nearly the same degree of heat in every variety of climate, and in all seasons of the year. This, however, is strictly true only of the higher orders of animals, the warm-blooded; the temperature of those constituting the division, called cold-blooded, being much influenced by external circumstances. The temperature of man is about 98 degrees of Fahrenheit's thermometer; that of some other animals is higher, — the temperature of birds, for example, being about 110 degrees. It is obvious, then, that man lives in a medium that is for the most part colder than his body, the temperature of the atmosphere being rarely at 98 degrees, and it sometimes, in our climate, descends to several degrees below zero. Capt. Parry, with his ship's company, in their voyage of discovery, wintered in a climate, in which the mercury not unfrequently was at 30 and 40 degrees below zero, and sometimes even as low as 50 degrees. Yet, under these circumstances, the bodies of warm-blooded animals have the power of generating heat to such an extent, as to keep their own temperature within two or three degrees

of its ordinary state. Capt. Lyon, who accompanied Capt. Parry in his second voyage to the Arctic Regions, found the temperature of an Arctic Fox on the 17th January, 1822, to be 106 degrees of Fahrenheit, while the temperature of the atmosphere was at 32 degrees below zero, making a difference between the temperature of the animal and that of the atmosphere of 138 degrees.

On the other hand, it has been ascertained by numerous and well-conducted experiments, that the human body can be exposed, even for a length of time, to a very high temperature, without affecting to any considerable degree that of the body thus exposed.

Dr. Fordyce and Sir Charles Blagden, in the year 1774, entered rooms heated to some degrees above that of boiling water, which is 212 degrees. They, in fact, proved by actual experiment, that a heat of 260 degrees could be borne without any extreme suffering. 'In order to render it certain, that there was no fallacy,' says Sir Charles Blagden, 'in the degree of heat, shown by the thermometer, but that the air which we breathed, was capable of producing all the well-known effects of such an heat on inanimate matter, we put some eggs and a beef-steak upon a tin frame, placed near the standard thermometer, and farther distant from the cockle than from the wall of the room. In about twenty minutes the eggs were taken out, roasted quite hard; and in forty-seven minutes, the steak was not only dressed, but almost dry.'

When they breathed on the thermometer, the mercury sunk several degrees, and when they expired forcibly, the air felt cool as it passed through the nostrils,

though it was scorching hot, as it entered then in inspiration.

These experiments were afterwards repeated, and it was found that the heat of the body soon rose to 100 degrees, but no higher, even when exposed to a temperature considerably above 212 degrees.

Children have been put into ovens heated to a temperature of 300 degrees, for the purpose of sweeping them out, without suffering any inconvenience; and Chaubert, whose exhibitions under the name of the Fire King, excited not long since great attention, both in Europe and this country, is said to have entered them when heated to 600 degrees.

Many other facts of a similar kind might be stated; but these are sufficient for our purpose: they very naturally lead to two important subjects of inquiry; viz. 1st. By what organs is the animal heat generated? 2d. By what means is its uniformity preserved?

1st. The Ancients had no accurate notions on the subject of animal heat. They believed that it was generated in the heart, and conveyed by the blood to all parts of the body. They thought that the purpose of respiration was to cool the blood, and thus prevent its heat from becoming excessive. This doctrine prevailed for many centuries: at length Mayow, whose discoveries respecting respiration have already been noticed, denied that the blood was cooled in the lungs, but asserted, on the contrary, that the purpose of respiration was to generate heat. So little at that time was known of chemistry, that he was unable to give much appearance of probability to his views, and they soon passed into neglect.

Dr. Black, after his discovery of the formation of carbonic acid gas in the lungs by respiration, suggested that this process was a similar one to that of combustion, and that heat was generated by the formation of carbonic acid gas, it being extricated by the union of the constituent principles of this gas. But it was at once objected to this theory, that, if all the heat was generated in the lungs, they must uniformly be at a much higher temperature than the other parts of the body, and this was known not to be the case; the difference of temperature being in fact trifling, not more than what could be easily accounted for on other principles. This objection was not to be easily overcome, and, consequently, the theory of Dr. Black received but little attention.

Not long after this, Dr. Crawford brought forward an explanation of the manner in which animal heat is generated, that was for a time adopted by most physiologists. He agreed in opinion with Dr. Black, that heat was generated in respiration, as in combustion, by the conversion of oxygen and carbon into carbonic acid gas; and the reason which he assigns for the fact that the lungs have not a much greater degree of heat than the other parts of the body, is, that the arterial blood has a greater capacity for caloric than the venous blood, and that a part of the heat formed in the lungs is absorbed by the arterial blood, and remains in it in that state which is known by the name of latent heat. When the blood is conveyed to the various parts of the body, the heat is given out whenever the arterial blood is converted into venous, as it is in the various processes of nutrition.

The heat generated in respiration does not all go into the arterial blood; a portion of it is absorbed by the air which comes into the lungs, and another portion is taken up by the aqueous vapor which passes from them. Numerous well-conducted and ingenious experiments were made by Dr. Crawford, which seemed to corroborate his views, and his theory, for a time, at least, received the sanction of the scientific men of Europe.

At length Mr. Brodie attempted to show that heat was not generated by respiration, and that its production in animals must be considered as a vital process, dependent in a great measure on the brain and nervous system. It was known that when the brain and the lungs were destroyed, either by removing the former or by decapitating the animal, the action of the lungs could be for a time maintained by artificially inflating them. It was also known, that during this process, the blood underwent the ordinary change in appearance; that is, was converted from a purple color to scarlet; the object of Mr. Brodie was to ascertain, if under these circumstances heat was evolved. After repeated trials, he was satisfied that it was not, but that, on the contrary, if the air thrown into the lungs were colder than the animal, it reduced the temperature of the body. Hence he inferred that the production of carbonic acid gas by respiration has no connexion with the generation of animal heat, but that this is dependent on nervous influence. His experiments were so simple, and apparently so decisive, as to receive at once the general assent of physiologists. But his conclusions are not admitted to be just at the present day; nor have the same results been

obtained from his experiments when repeated by some eminent men. He seems to have overlooked the fact, that it was not maintained by Dr. Crawford's theory that heat was evolved in the lungs, but that, on the contrary, it was agreed that it was absorbed as fast as it was generated by the air, by the aqueous vapor, and by the arterial blood.

Dr. Wilson Philip supposed that the rapid cooling of the body, when the lungs were artificially inflated, was owing to the large quantity of air thrown into them; and in his experiments, and in those of Mr. Legallois of France, it was found, that when artificial respiration was produced by a moderate quantity of air, the body, though it cooled, did not cool so fast as a dead body in which this process was not resorted to; and that it parted with a greater degree of heat, while cooling, than dead animals did under similar circumstances; a clear proof that heat was generated by artificial respiration.

These, and other experiments of a similar character, have induced most physiologists of the present day to adopt what is usually called, the chemical theory of the generation of animal heat. It must be confessed, however, that it is not without its difficulties, but at the same time, it cannot but be acknowledged, that it is embarrassed with fewer than any other that has ever been proposed. Though it is called a chemical theory, it is so only in a limited sense, the laws of chemistry being, as in all the other operations that go on in the living body, modified and controlled by the laws of vitality. The brain and nervous system, no doubt, perform an

important part, if not in the generation, at least in the evolution of animal heat.

There is one fact worthy of notice, as it seems to show that there must be an intimate connexion between respiration and animal heat; and that is, that in those animals whose respiratory apparatus is the most extended, the temperature is uniformly highest. Birds, whose organs of breathing extend over a large part of the body, and who consequently require a great quantity of air, have a higher degree of temperature than other animals : it is twelve degrees above that of man ; while in cold-blooded animals, as fishes, whose temperature is not much greater than that of the medium in which they live, but a very small quantity of blood at any one time is subjected to the effects of respiration.

2d. We come next to the second inquiry, viz. : By what means is the temperature of the animal body kept nearly uniform ? All animals ordinarily live in a medium whose temperature is lower than that of their bodies, and at the same time retain nearly an uniform degree of heat. When subjected to severe cold, their bodies still are kept sufficiently warm to preserve life, by the increased action of those causes which generate and evolve animal heat. These, under ordinary circumstances, are sufficient for the purpose ; but when the body is debilitated by any cause, and exposed for a long time to a very low temperature, the vital powers are destroyed, and death ensues.

The more difficult point to settle is, how animals, when exposed to a high temperature, are capable of resisting it, or, in other words, what means have they of

generating cold. Some recent experiments warrant the belief, that, when thus exposed, the temperature of the body is increased more than was formerly thought, being sometimes raised ten or twelve degrees. It seems to be probable, also, that the same degree of heat is not generated by the body in a high temperature, as in a low one: it is certain that less heat is formed in the lungs in summer than in winter. This was very strikingly shown by Dr. Edwards, of Paris, in some experiments which he made on birds. He exposed those animals to a freezing mixture, for the same length of time, in February and July, and he found that they 'cooled six or eight times as much in the summer as in the winter months.'

But admitting that a less degree of heat is generated in a high than in a low temperature, this alone would not be sufficient to account for the power which the body possesses, of resisting a very great degree of heat. The principal cause, no doubt, is the one which was originally suggested by our countryman, Dr. Franklin, and that is, the increased exhalation which takes place from the lungs and the whole surface of the body, when it is exposed to a high temperature. The body is thus kept cool, on the same principle that inanimate bodies are cooled by evaporation. It is said to be a common practice in India to put bottles of wine, covered with wet cloths, in a current of air, even in the heat of the day, for the purpose of cooling it.

But it was rendered certain by an experiment of Mr. Delaroche, that it was in the way first suggested by Dr. Franklin, that the body was enabled to resist a great

increase of temperature. He put animals into a warm atmosphere, saturated with moisture, so as to prevent in great measure the exhalation from their lungs and the surface of their bodies. These animals immediately become heated, as if they had no power of cooling themselves, or resisting the temperature to which they were exposed.

We can understand from this why it is that in summer those days are most oppressive, in which the atmosphere is loaded with moisture, even though the thermometer does not indicate so great a degree of heat as at many other times.

CHAPTER V.

OF SECRETION.

The term secretion, in its strict sense, has the same meaning as that of separation ; but in physiology it is used to denote that process by which various substances are separated from the blood, either with or without experiencing any change during their separation. Not only is this process called secretion, but the same term is also applied to the substance thus separated. Thus we say, that by the process of secretion, bile is formed by the liver ; and we also say that bile is the secretion of the liver.

The function of secretion is of great importance in the animal economy. By it the nutritive parts of the blood are separated from it, and made to contribute to the nourishment and growth of the body. It is by this means, too, that various substances are formed, which are intended to accomplish very important purposes in the system; and it is moreover by means of secretion, that various noxious substances are discharged from the blood.

Many of the secreted substances differ very materially in their composition, if we may judge by chemical

analysis, or their external appearance, from the blood itself; and yet it was for a long time maintained, nor is the doctrine without its advocates at the present day, that the process of secretion did not change their character, but merely separated them from the blood. Though it is probable that the simplest of the secreted substances may exist in the blood in the same state in which they are separated from it, it is also certain that no trace can be found in this fluid of some of the substances that are formed by the process of secretion.

Various modes of examining this subject have been adopted. Some physiologists have made a division, founded on the different nature of the secreted substances. But to this it is objected, that we probably do not know all of them, or if they are known, it is difficult, if not impossible, so to analyze them, as to form, in this way, a satisfactory arrangement. The mere fact, that so many different divisions of these substances have been proposed by different writers, is enough to show that our knowledge on this subject is not yet sufficiently precise for the purpose.

The simplest division, and that which on the whole is perhaps the best, certainly the most convenient, is the one that is founded on the difference of the secretory organs. In describing these, notice can be taken of such of the secreted substances as may be thought proper. This arrangement therefore will be adopted.

The secretory organs are of three kinds: 1st, The exhalent vessels; 2d, The follicles; and, 3d, The glands.

All authors have not been agreed in calling the ex-

halent vessels secretory organs; and the function which they perform has been by some called exhalation, secretion being considered a more complicated process. But, according to the definition of secretion already given, it is certainly proper to consider the exhalent system among the agents of this function.

The exhalent vessels are supposed by some to be a continuation of the capillaries, while others maintain, that the function of exhalation is performed by the capillaries themselves. It has been before stated, that the arteries terminate in a set of minute vessels, called capillaries, and from these it has been imagined that the exhalents are sent off. These latter vessels, which are believed to be very abundant on the internal cavities of the body and on the surface, have the power of separating various substances from the blood : at any rate, we know that this process is constantly going on there, and it is of but little consequence whether it be performed by the capillaries, or another set of vessels. The exhalations have been divided into two kinds, the internal and the external.

The internal exhalations are those which take place within the body. The serous membrane, which covers the organs within the head, the chest and the abdomen, is continually, during life, exhaling serous fluid, which has a close resemblance to the serum of the blood. This fluid is thrown out by this membrane to keep the surfaces on which it is exhaled, in a moist state, and thus to enable the organs to move easily on each other.

The cellular texture also exhales a serous fluid, and

in some forms of disease, this becomes excessive, producing a general dropsy.

The fat is also thrown out by the process of exhalation, from the cellular texture. It is contained in cells, and it is supposed to be in a fluid state, when it is first exhaled. Its principal use in health seems to be from its physical properties, forming a sort of cushion under the skin, which protects it from injury in walking, standing, and other positions of the body.

During sickness, the fat, or adipose substance, as it is called, is supposed to aid in nourishing the body, being taken up, for this purpose, by the absorbent vessels, and conveyed into the blood. It is considered an unfavorable symptom in disease, if emaciation does not take place, because it shows a want of power, in the absorbing system, which is among the last to be affected. Hybernating animals, those that become torpid during the winter, are uniformly found to be much emaciated on the return of spring, they having been nourished during their hybernation, by the absorption of their fat.

The fat is usually of a yellow color, and inodorous.

The ligaments which surround the joints, are lined by the serous membrane, which secretes a fluid called synovia. This fluid is designed to facilitate the movements of the joints, by lubricating them, and thus enabling them to move with ease. It has been supposed by some, that this synovial membrane is not precisely like the serous membranes: the difference, if there be any, is so slight, that it is not easily detected.

In the cavities of the long bones, there is found a substance somewhat resembling fat, which is known by

the name of marrow or medullary substance. It is secreted by a delicate membrane, that lines the cavities of the bones. The use of the marrow does not appear to be known. It is not formed for the purpose of rendering the bones less brittle, as has been supposed by some, because it is most abundant in the bones of old persons, which are much more brittle than those of young ones.

These are the most important of the internal exhalations.

The external exhalations that are next to be noticed, are the cutaneous and the pulmonary; the one taking place from the skin, and the other from the mucous membrane that lines the internal parts of the lungs, wind-pipe, fauces, and mouth.

The cutaneous exhalation or transpiration, as it is called, is of two kinds, one of which is insensible, and the other sensible; the first is called *insensible transpiration*, and the second *sweat*. The fluid that is thrown off in this way from the skin, consists chiefly of water, with a small quantity of acid, and salts of different kinds with a minute portion of animal matter.

Many attempts have been made to ascertain the quantity of insensible transpiration, that is thrown off in a given time. Sanctorius followed up a series of experiments on the subject for thirty years, but the results at which he arrived have never been considered satisfactory.

Lavoisier and Seguin have investigated the subject with great skill, and no doubt is entertained of the general accuracy of their conclusions, though in investigations

of this kind, it is difficult to arrive at anything more than approximations. The following are among the results of their inquiries.

1st. The greatest quantity of insensible transpiration, including that from the lungs as well as the skin, given off in a minute, is thirty-two grains.

2d. The least quantity was eleven grains.

3d. The average, eighteen grains; eleven from the skin, and seven from the lungs.

4th. During the period of digestion, a less quantity is thrown off than at any other time in health.

The uses of the cutaneous transpiration are important; it renders the skin more pliable, and the sense of touch more delicate. It is also, as we have seen before, the most important agent in cooling the body, when it is exposed to a high temperature, and there is reason to believe, that it carries out of the body some noxious property of the blood. It is certain that when it is lessened, or altogether stopped, the health becomes impaired, and many diseases are removed when copious perspiration is produced.

The pulmonary transpiration very closely resembles that of the skin. This aqueous exhalation, that is thrown off by the lungs during respiration, was at one time supposed to be formed in the lungs by the union of hydrogen from the blood, and oxygen from the inspired air, thus forming water. This is not, however, the opinion at the present day. It is now believed, that this fluid is either given off directly by the blood, in the same way as the cutaneous transpiration, or that it is the watery part of the mucus, that is secreted by the mucous membrane of the lungs and air passages.

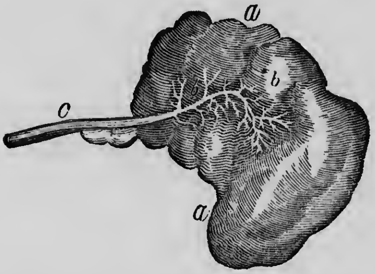
All the internal cavities that open externally, are lined by a mucous membrane, and this membrane constantly secretes a fluid which is known by the name of mucus, and which has a close affinity to the transpiration from the skin. Some are of opinion, that the pulmonary transpiration is merely the watery part of the mucus, while others maintain that the watery exhalation takes place in addition to the secretion of mucus.

2d. The Follicles. The follicles are very small sacs or bags, which are found only in the skin and the mucous membranes. They are therefore of two kinds, the cutaneous and the mucous. The pores that are seen on almost every part of the skin, are the outlets of the cutaneous follicles. They secrete an oily unctuous substance, which mixes with the transpiration, and lubricates and softens the skin. When it does not pass off readily, the pores become obstructed, and appear as if they were filled with small worms. There is a small follicle at the root of each hair. The wax in the passage of the ear is secreted by the follicles.

Every part of the mucous membrane is more or less abundantly supplied with follicles. They secrete a fluid, which is supposed to resemble very closely mucus; but this cannot be known with certainty, as it is impossible to obtain them separate. Some of these follicles exist on the tongue, and the small openings that are seen on the tonsils or almonds of the ears, which are situated in the back of the throat, are supposed to be the outlets for the secreted fluids of these small organs.

3d. Of the Glands. Glands are bodies of various size, more or less of a rounded form, situated in various

parts of the body. They secrete substances of very different character, and, in some instances, having little or no resemblance to the blood from which they secrete them. In the more perfect glands there is found one or more arteries, which carry the blood to this organ, a set of veins, which return a portion of it, and another set of vessels, which usually unite in a common trunk called an excretory duct, which conveys the fluid formed by the gland to its place of destination. The intimate nature of the glandular structure is wholly un-



A GLAND with an excretory duct. *a a* The substance of the gland irregular and lobulated. *b b* The small branches, by which the excretory duct arises from the gland. *c* The trunk of the excretory duct fully formed.

known, and it is by no means determined whether the secretion is performed by this structure, or whether it is dependent on the action of the vessels alone. In some instances, where the secreted fluid differs very materially from the blood, the secretory apparatus is simple; while in other cases, in which it bears a close resemblance to the fluid from which it is separated, the organ by which it is effected is of a complicated char-

acter. It is probably impossible to settle a question of this kind by actual experiment.

The glands, as has been observed, are of very various size. The lachrymal gland, which secretes the tears, is a flat body, not larger than a small almond, while the liver, by which the bile is formed, weighs from two to three pounds in an adult in health, and sometimes, in disease, weighs fifteen or twenty pounds. The liver is supposed to differ also from the other glands in this respect, that its secretion is not made from the arterial blood. This is by no means a settled point, as some contend that its secretion takes place as in the other glands, while others are of opinion that the bile is principally formed from the blood of the veins. It is certain that the liver has an artery, called the hepatic artery, a set of veins to return the blood to the heart, and an excretory duct, to convey the secreted fluid into the intestines: in addition to these, a very large vein, formed by the union of several of the most important veins coming from the abdominal viscera, and called the vena portæ, enters into it, and is distributed throughout its substance. The blood in this vein is necessarily of a very impure character; it has parted with its nutritive and vital principles, and it is about to be returned to the heart, to be again sent to the lungs, to undergo the essential change which respiration effects in it. In this state it may be supposed to be loaded with noxious principles, and that it is sent to the liver for the purpose of parting with some of them. This is the view that is taken by some physiologists; while Bichat and others maintain, that the bile is formed from the arterial

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blood, and a third class, at the head of which stands Magendie, are of opinion that it is secreted from both the arterial and the venous blood.

There are then but three known kinds of secretory organs: by the first the secretion is thrown out directly from the blood-vessels; by the second, it is formed by the intervention of a small sac or vesicle, called a follicle; and by the third, it is effected by a much more complicated apparatus known by the name of glands.

It is by no means easy to explain the manner in which secretion is performed. The same fluid is carried to the different secretory organs, and they separate from it substances that not only differ in some instances very essentially from the blood, but which also have little or no resemblance to each other. In fact, the elementary principles of some of the secretions cannot be detected in the blood, and their formation is wholly inexplicable in the present state of our knowledge.

Various theories have been proposed at different periods on this subject. One of the earliest attributed secretion to a kind of fermentation that took place in the secretory organs. There is, however, no evidence that any such fermentation does take place; nor is there any reason to believe, that if it does, it would be capable of producing the effects which have been attributed to it. It is probable, that the advocates of this theory used the term fermentation, in a sense somewhat different from the ordinary one; but even admitting this, it does not remove the difficulty.

The hypothesis that succeeded to this was a mechanical one, which supposed that the secreted substances already

existed in the blood, without explaining how they got there, and that the secretory apparatus served as a kind of sieve or filter, through which only its peculiar secretion could pass, — the rest of the blood returning by the veins. A sufficient objection to this is, that it assumes what no one now believes, that the various secreted substances exist already formed in the blood.

Some experiments have been made to show that secretion was dependent on nervous influence. The division of the par vagum, a nerve that goes from the brain to the stomach, stops the secretion of the gastric liquor, and it is well known that some affections of the mind have a power over the secretions. Grief often, times produces an increased action of the lachrymal gland, and the thought of savory food, causes an increased flow of saliva. Though the nerves probably have an influence in the higher orders of animals over the secretory organs, yet there are some animals in whom no nervous system can be discovered, and yet in them secretions go on.

The doctrine which is received with the greatest favor at the present day, is what may be called the chemical theory of secretion. According to this hypothesis, the secreted substances do not exist in that form in the blood, the elements of them only being there; and it is by the combination of these elements in various proportions, that all the secretions of the system are produced. There are no doubt some well-known facts in chemistry, that give a plausibility to this view of the subject. It is certain, that a few elements, united in different proportions, are capable of

producing compounds of very different characters. But giving to chemistry all the power that its warmest advocates can claim for it, it must still be admitted, that there is a controlling power, which is vital agency. If it were not so, all the secretions could be made out of the body as perfectly as they are formed in it ; and if the blood, which is carried to the different secretory organs, was acted upon only by chemical laws, why would not the results be the same in every instance ? Or, in other words, what should produce a difference in the secretions, if they are the effect only of the combination of different elements of the blood in various proportions under the influence of chemical laws alone? But even admitting the influence of vitality, the subject is not without its difficulties, for we find that some substances are secreted, the elements of which have never been found in the blood, or, if found at all, only in very minute quantity.

Of some of the Secreted Fluids.

It may be proper to say a few words of the nature and chemical composition, as far as they are known, of some of these fluids.

Of the Saliva.

This is formed, as has been already stated, by three pairs of glands, situated in and about the mouth. It is poured out very copiously at all times, but more especially while eating. It is doubtful whether it contributes

in any degree to the process of digestion : its principal use in this process seems to be to prepare the food, by mixing with it, so that it can pass with ease into the stomach. It assists also the voice, by keeping the mouth in a moist state.

Pure saliva has never been subjected to analysis, because it is nearly impossible to obtain this fluid, unless mixed with the other fluids of the mouth. It is no doubt true, however, that the saliva constitutes the greater part of the fluid thus obtained, so that the result of any chemical examination of it may be considered sufficiently accurate for all practical purposes. The saliva is a mild, viscid fluid, without smell, taste or color, and a little heavier than water. One thousand parts of it contain nine hundred and ninety-two parts of water, and the remaining eight parts are made up of various kinds of salts, with a small quantity of mucus, and a minute portion of animal matter of a peculiar character. The properties of the saliva are not always the same : it sometimes contains acid, and it is well known to be acrid after long fasting. It is on this account that it is a popular remedy in that state for ring-worms, and some other cutaneous affections.

Of the Pancreatic Fluid.

The pancreas, or sweet-bread, is a gland situated behind the stomach ; and its secretion, as was observed when treating of digestion, is poured into the first intestine. From the resemblance, both in structure and appearance of this gland, to the salivary glands, it has

been thought to serve the same purposes. The pancreas secretes but a small quantity of fluid, and it is not easy to obtain much of it for the purposes of examination. Mr. Magendie, who has probably made the most experiments on the subject, states it to be of a yellowish color, saltish taste, inodorous, possessing alkaline properties, and capable of being coagulated by heat. He further adds, that the secretion of it is not increased during digestion, but rather diminished. The uses of this fluid are not known ; it does not resemble the saliva in its properties, so much as has been thought.

Of the Gastric Juice.

It is remarkable that this fluid, which is known to possess properties of such activity, should so closely resemble the saliva, as it seems to do. Chemical analysis has not been able to detect in it anything which can account for its power of dissolving the different substances that are put into the stomach. Dr. Prout has recently ascertained, that during the process of digestion, muriatic acid is present in the stomach ; it is this acid, which by its combination with soda, forms common salt. It is not supposed, however, that the acid exists in the gastric juice, but that it is in some way evolved from the food, and then becomes an important agent in converting it into chyme. The prevailing opinion is, that the gastric fluid has neither acid nor alkaline properties. It is remarkable not only for its solvent power, but for two others. The first of these is the power of coagulating albuminous fluids,

and on this depends the process of making cheese, as has been already stated. The second is the power of preventing putrefaction, and of even removing in some degree the effects of it when it has already commenced. Animals, that live on carrion, often take their food in a half putrid state, and it has been found that the first operation of the stomach is to remove the fœtor from it. Experiments made with the gastric juice out of the body, show conclusively that it has, to a certain extent, the property of preventing putrefaction. Notwithstanding it is possessed of such wonderful properties, yet, on analysis, nothing can be detected in it essentially different from the constituent principles of that mild, inert fluid, the saliva.

Of the Bile.

This fluid, as is well known, is secreted by the liver, the largest gland in the body. It differs very materially, both in appearance and properties, from the blood. It is of a greenish, yellow color, of an excessively bitter taste, thick, sometimes transparent, and sometimes opake. It contains water, albumen, resin, and a great variety of salts. The purposes of the secretion of the liver appear to be two-fold ; the bile probably assists in some way, which is not precisely known, in the formation of chyle, and there is reason to believe that it is made the vehicle to carry out of the system, under certain circumstances, substances, which, if retained, might prove noxious.

Of the Tears.

The tears, which are secreted by the lachrymal glands, consist principally of water. They are limpid, inodorous, and of a saltish taste. They contain minute quantities of common salt, phosphate of soda, soda, lime, and mucus.

CHAPTER VI.

OF ABSORPTION.

Absorption is that process by which the substances that are designed to contribute to the nourishment and growth of the body, are conveyed into the blood. There is another office which is performed by another part of the absorbent system. The particles of which the body is composed, are constantly changing; they lose their power of performing their functions; they are then removed by a distinct set of absorbent vessels, and carried into the veins, and new ones are brought to supply their place. There are then two sets of absorbent vessels; one of them, connected with the digestive function, is situated in the abdomen; the other is spread throughout the body. The vessels of the first are called lacteals, and those of the second lymphatics. Each of these will be described separately; and after doing this, we shall then examine the question, whether absorption is performed by any other vessels.

The lacteals, as has been before said, are so called, because the fluid they contain, resembles milk in appearance. They take up the chyle from the small intestines, and convey it to the thoracic duct. This part of the absorbent system may be said to consist of lac-

teals, mesenteric glands, and the thoracic duct; this last, however, is connected both with the lymphatics and the lacteals.

The lacteals originate in the inner coat of the small intestines, but in what manner is not precisely known. Some have undertaken to describe the mouths of the lacteal vessels which take up the chyle; but most anatomists have been unable to discover them. These vessels are very minute at their origin, and of a very delicate structure, in their whole course. As they go from the intestines, they pass along the mesentery, which is a very thin membrane, formed by a duplicature of the serous coat of the intestines; in passing through the mesentery, they are seen to increase in size, very much in the same manner as the veins do, which begin in numerous small branches, that soon run into, and are connected with others, fewer in number, but of larger size. The lacteals are furnished with a large number of valves, which are of sufficient power, under ordinary circumstances, to prevent the retrograde motion of the chyle. As they pass along the mesentery, they are connected with numerous small bodies, known by the name of the mesenteric glands. The use of these is unknown. The various branches of the lacteals soon unite into three or four trunks, which pour their contents into the thoracic duct.

This vessel is situated near the spine, and it differs from the other absorbent vessels chiefly in its size, being much the largest of any. Its coats, though thin and transparent, are strong and elastic, and, like the other absorbents, it is furnished with many valves. At its

commencement, there is a sort of reservoir, which is called the receptacle of the chyle, (*receptaculum chyli.*) The thoracic duct usually consists of a single trunk; sometimes, however, there are two of nearly equal size; while in other instances, there has been found one of the ordinary size, and one or two smaller ones. It passes up along the spine, from the place where it originates, which is about the fourth dorsal vertebra, to half an inch above the subclavian vein; it then bends down and pours its contents into this vessel.

The other set of absorbent vessels are called lymphatics. They received this name from the fluid they contain, being called lymph. They are very numerous, probably in all parts of the body, though they have not been discovered in the eye or the brain. Their structure resembles that of the lacteals.

They may be divided, from their situation, into two classes, the superficial, and the deep-seated. They are connected like the lacteals, with glands, which are called lymphatic glands. These small bodies are more numerous in some parts of the body than in others; several of them may be found in the groin, under the arm and in the neck. From exposure to cold and other causes of irritation, they frequently inflame and enlarge, and are vulgarly known by the name of kernels. They often become the seat of disease, particularly of the scrofula, or king's evil. The lymphatic vessels of the extremities frequently inflame from slight causes. A trifling wound of the finger will oftentimes be followed by inflammation of some of the lymphatics of the arm, and these little vessels may in that state be

traced by their red color up to the arm-pit, in which some of the small glands will be found enlarged, sore, and perhaps painful.

The lymphatic vessels, in their course towards the thoracic duct, become fewer in number, and somewhat larger, though they never attain any considerable size. They pursue a similar course with the lacteals, and part of them finally pour their contents into the thoracic duct, and the remainder terminate in a trunk on the right side, about as large as the thoracic duct, though much shorter. The absorbents were not known as a distinct system, by the ancients. The lacteals were discovered by Aselli, in 1622, and the lymphatics about thirty years afterwards. A complete knowledge of the absorbent system was not obtained at once; and the fact of the termination of the lacteals in the thoracic duct, was not known till some years after the discovery of these vessels.

The lacteals and lymphatics, though they resemble each other very closely in their structure and termination, differ as to the nature of the fluids which they convey, and also as to the purposes of their functions. The lacteals open in the small intestines, and take up the chyle. The mouths by which this fluid enters, have never been discovered, though the contrary has been maintained. These mouths seem to be furnished with the power of selecting from the mass that is passing through the intestines, the fluid which is to be conveyed into the blood, and become a part of it. The lacteals, therefore, have the power of taking up the chyle only; or perhaps it would be more proper to say,

that they are endowed with the power of rejecting every thing that is presented to them but the chyle ; while the lymphatics not only take up all the various constituents of the body, both fluid and solid, when they have

A A is a piece of a small intestine. *b b b b* are the superficial lacteals. *c c c* is the mesentery, a delicate, but firm membrane, consisting of two layers, by which the intestines are connected with the spine, and within the folds of which the deep-seated lacteals pass. *d d d* and *e e e* the two sets of absorbent glands *f f* the receptacle of the chyle. *g* the thoracic duct. *i i* the lymphatics, coming from different parts of the body. *h* the aorta, the great artery.

ceased to be of use to the parts to which they belonged, and convey them into the blood, either to be thrown out of the body, or to be rendered again fit for the purposes of life, but they also absorb foreign and extraneous substances, when presented to their mouths.

Medicines will act as powerfully, when introduced into the system through the absorbents, as when they are given by the stomach.

The ordinary functions of the body in health require incessant action of the absorbents : the circulating system, with its myriad of minute vessels, is constantly depositing new particles, and the old ones are taken away by the absorbent system. Though the vessels of this system have not yet been traced in all the animal organs, there can be no doubt that they are all furnished with them. No part of the body is exempt from this process of composition and decomposition, the former being effected by the vessels of the circulating system, and the latter by those of the absorbent system.

Some of the uses of the lacteals and lymphatics seem to be well understood ; the former convey the chyle, the product of digestion, into the mass of the circulation, and the latter carry another fluid, somewhat resembling the chyle, called lymph, which is collected from all parts of the body. The uniformity in the character of the lymph, has led some physiologists to doubt whether the lymphatics take up all the extraneous bodies that are known to be removed by the absorbent system.

The nature of the lymph is not yet well understood. The term has been applied to a variety of fluids, but it is now restricted so as to denote that only which is contained in the lymphatic vessels. Mr. Magendie denies the common doctrine, that the lymph originates from the decomposition of the component parts of the body, but maintains it to be a certain part of the blood, which

instead of returning by the veins, is carried back to the heart by the lymphatics and the thoracic duct. He rests his opinion principally on the uniformity of the character of the lymph. It is foreign to our purpose to enter into a discussion of this subject; it may be proper however to remark, that this does not seem to be a sufficient reason for abandoning the received notion, which considers the absorbents as the principal agents, which remove the various parts of the body when they no longer perform the functions for which they were intended.

The lymph, when examined out of the body, is usually of a reddish color and of a saline taste. It soon coagulates and becomes of a deeper color. This coagulated lymph consists of two parts, one of which is solid, with numerous cells, and these cells are filled with fluid. A thousand parts of lymph contain nine hundred and twenty-six parts of water, sixty-one of albumen, and the remaining thirteen parts are various kinds of salts.

The office of the absorbent glands, the mesenteric and lymphatic, is not known. It is presumed to be important, because every absorbent vessel in its course passes through one of them; but it is also true, that they are found only in the higher order of animals. Conjecture has assigned to them two uses; the one is to assimilate the fluid which is passing through the absorbent system to the blood, with which it is soon to be mixed; and the other is to resist the introduction into the circulation, of foreign noxious substances.

It was known long before the discovery of the lacteals and lymphatics; in fact, even in the time of Galen,

who lived a little more than a century after the birth of our Saviour, that absorption took place, and this office was supposed to be performed by the veins.

For many years after the discovery of the absorbent vessels, it was thought that they were not the exclusive agents of absorption, but that the venous system also performed a part. This was the opinion of Haller, Boerhaave, and other distinguished physiologists, and was in fact the prevailing one till about the middle of the last century. Though the veins had never been proved to be the agents of absorption by direct experiment, it was still asserted that it had been ascertained, by injections, that there was a free communication between the venous and the absorbent systems, proving an identity in their functions; it was also known that absorption took place in parts where no absorbents could be detected, and it was thence inferred, that it was accomplished by the veins. Dr. William Hunter, of London, and Dr. A. Monro, sen. undertook a series of experiments about the same time, which induced them to believe that absorption was performed exclusively by the lacteal and lymphatic vessels. They maintained that in those cases where a communication was discovered by means of injections between the absorbent and venous systems, it was the effect of accident, owing to the rupture of one or more vessels in consequence of the force with which the injection was thrown in. They extended their researches also to those parts, which had before been supposed to be destitute of absorbents, and in some of these they discovered these vessels, which they thought authorized them to infer that they existed

in all, though they were in many parts of so delicate a structure, as to elude discovery.

Mr. John Hunter made some experiments on the subject about this time, that seemed to remove all doubt upon the subject, and physiologists became agreed in rejecting the doctrine of absorption by the veins. He opened the abdomen of a living dog, removed from a portion of the intestine all its contents; he emptied the veins of their blood by puncturing them; he tied the arteries that went to the part, and thus prevented blood from being carried there; he then injected into the intestine warm milk, and kept it there by placing ligatures above and below, and then returned the intestine into the abdomen. In half an hour he drew it out; on examination he found that the veins were as nearly empty as before, that they contained no white fluid, while the lacteals were full of it. From this he concluded that the lacteals absorb, and that the veins do not.

For a time there seemed to be no subject in physiology on which there was less diversity of opinion than on that of absorption; the only question appeared to be to whom belonged the credit of having first established the fact that the lacteals and lymphatics were the exclusive absorbent vessels. But recently this opinion has been controverted by Mr. Magendie, of Paris, one of the most distinguished physiologists of the age, who has supported his views by so many ingenious and well-conducted experiments, as to satisfy most persons of their correctness. He repeated the experiments of Mr. Hunter, but obtained different results. The same thing has happened to others. From numerous experiments,

he came to the conclusion, that the lacteals absorb the chyle only, but do not take up the various liquids that are taken into the stomach, and which are known to pass unchanged into the blood. If diluted alcohol be given to a dog while he is digesting solid aliment, the chyle, on examination, in half an hour, will not be found to have the odor of alcohol, though it will be very perceptible in the blood, and alcohol can be obtained from it by distillation. Water and other drinks which are not converted into chyle, he believes are taken up and carried into the circulation by the veins of the intestines.

Having established, by numerous experiments, that absorption by the veins takes place in the intestines, Mr. Magendie instituted others, to show that the veins have this power in other parts of the body. It is unnecessary to relate many of these: there is one, however, of so decisive a character, as in great measure to establish his views, if nothing else could be adduced in support of them. He divided all the parts of the hind leg of a dog, except the artery and the vein; a poisonous substance was then applied to the foot, — in four minutes its effects were visible, and in ten minutes the animal died. It seems hardly possible to suppose that the poison was introduced into the system in this experiment, except throught he vein; but to avoid all possibility of error, he made another. He introduced small leaden tubes into the artery and vein, secured them there by ligatures, and then divided the vessels, so that all the blood must pass through these tubes in going from the extremity to the body of the animal; yet

the poison, applied in the same way, produced the same result as in the former experiment.

On the whole, then, it may be said with regard to absorption, that it is performed by the lacte , the lymphatics, and the veins. The former, under ordinary circumstances, take up only the chyle, which is destined to the nutrition of the body. The lymphatics carry a thin semi-transparent fluid, known by the name of lymph, which may sometimes serve the purpose of nutrition, but which it probably does not do, while the lacteals are able to perform their functions. The veins absorb from the intestines liquids of various kinds that have been taken into the stomach, and which have not been converted into chyle, and in other parts of the body, they perform the ordinary office of lymphatics. If we admit the absorption by the veins, it will perhaps satisfactorily account for the fact, that the venous system has so much greater capacity than the arterial; for if it had no other office to perform, than to return the blood that had been distributed to the various parts of the body, it would be reasonable to suppose, that the capacity of the veins would be less than that of the arteries; but it is known to be greater, and if it has the function of absorption to perform, there would seem to be a reason for it.

Whatever be the agents of absorption, it is a process that goes on unceasingly in health and disease. In the former, it conveys the nutritive part of the food into the blood, and carries into the same fluid the several constituents of the different organs of the body, when they are no longer able to perform their original functions.

In some forms of disease, its action is more obvious. Water, that is poured out in the different kinds of dropsy, is often absorbed with great rapidity; and it is by absorption, that nature often removes hard and solid tumors from various parts of the body. Perhaps the effect is no where more distinctly seen than in the neighborhood of an aneurism. An aneurism is an enlargement of an artery, one of the vessels which distributes the blood throughout the body. From accident or disease, one of the coats of this vessel is weakened or destroyed ; a swelling forms at the place, and it soon becomes a pulsating tumor, and if it be in a large artery, it beats with great force. This disease frequently occurs in the aorta, the largest artery that goes off from the heart. A large tumor is formed in the chest; it presses against the ribs and breast-bone, and finally they are absorbed. Now the absorption of these bones is not produced by the aneurism; it is a process that is constantly going on, but it is the aneurism which prevents the deposition of the new particles of bone, which, under ordinary circumstances, would have been deposited to supply the place of those taken up by the absorbents.

There has been much diversity of opinion on the question of cutaneous absorption; some maintaining that the skin absorbs, while others deny it, and both opinions being supported by numerous experiments. The point is not yet settled; it is probable, as it oftentimes happens, that the truth lies between the two parties. There is reason to believe that the skin does absorb in a

moderate degree, in some parts of the body, though it has not the power to the extent which has been claimed for it.

Those who have denied cutaneous absorption have asserted, that the error arose from the vapor of the substance employed in the experiment being allowed to enter the lungs, and that if pains were taken to guard against this, no absorption took place. In other experiments, this has been carefully guarded against, and distinct traces of the substance used in the experiment have been found in some of the secretions.

It is difficult to explain the mode in which the absorbents act, or, in other words, to show in what manner they take up and circulate the fluids which pass through them. It has been supposed by some, that these fluids are drawn into the mouths of the absorbents, by a kind of capillary attraction, while others have thought that it is the result of a vital law that cannot be explained on mechanical principles. There can be no doubt that the lacteals have a power of selecting such parts of the contents of the intestines, as can be rendered tributary to the purposes of nutrition, and rejecting such as could not be assimilated with the blood. But if it be admitted that the fluids are taken into the mouths of the absorbent vessels by a kind of capillary attraction, it will not explain how the fluids are carried along these vessels. The coats of the absorbents are remarkably thin and delicate, and destitute of muscular fibres. They have not, therefore, the contractile power of the capillary vessels, and consequently cannot themselves propel the fluids which they contain. Neither is there

connected with the absorbent system, a powerful muscular organ, like the heart, which, by its contraction, can throw a fluid through the system of vessels with which it is connected. We must therefore regard the course of the fluids through the absorbent system, as one of those operations, that are dependent on vital laws, and not to be explained on the common principles of mechanics.

CHAPTER VII.

OF NUTRITION.

The process by which the body increases in size, and the waste of its organs is repaired, is called nutrition. Its agents are supposed to be those minute vessels, that are situated between the termination of the arteries, and the commencement of the veins, and which are known by the name of capillaries. These vessels are distributed largely to all parts of the body, and have the power of separating from the blood particles identical in character with those of which the various organs of the system are composed.

It has been before remarked, that a species of composition and decomposition is constantly going on in the body during life. The first of these is effected by the blood-vessels, and the latter by the absorbents. By digestion, a nutritive fluid, called chyle, is extracted from the food taken into the stomach; the lacteals convey this into the blood, and partially assimilate it to that fluid; but it is not yet fit for the purposes of life. It is carried by a distinct set of vessels into the lungs, where it parts with some of the noxious principles it derived from digestion, and it also receives others from the air, which, as it were, impart to it vivifying prop-

erties. In this state it is returned to the heart, and this organ sends it through numberless vessels to every part, for their growth and nourishment. But the mere circulation of this fluid would not be sufficient; a portion of it must be left in each of the organs to supply the waste, and this is probably done by the minute capillary vessels of the part. Under ordinary circumstances, these vessels cannot be seen by the eye, even when aided by the microscope: they are so minute as to elude all examination in their natural state. But, small as they are, they are agents whose functions cannot be dispensed with in the animal economy. One set performs an important office in the lungs, as has been already noticed, and the other, spread throughout the system, is carrying nourishment to all the organs. The latter have received the name of the nutritive arteries. The nutritive process is a sort of secretion by which different substances are separated from a common fluid, the blood. Thus, one set of these vessels deposits the fibrin to form the muscles, and another, the earthy and animal parts of the bone. We are wholly ignorant how this is accomplished; but of the fact there is no doubt.

Nearly all the parts of the body are continually, during life, subjected to this process; the old particles are taken up by the absorbent vessels, and new ones are deposited in their place by the nutritive arteries. The hair, the nails, the outer covering of the teeth, the coloring matter of the skin, and perhaps the cuticle, form, almost, if not the only exceptions. There is a great disproportion between the processes of composition and

decomposition, at the different periods of life. Before the body has attained its full size, the function of nutrition is in great activity; a large amount of food is taken when compared with the size of the body; digestion is rapidly and easily performed, and the various organs are supplied with new particles, not only to supply the place of those that have been removed by the absorbents, but also to contribute to their growth. In the adult, the balance is restored between the nutritive arteries and the absorbents, the former, furnishing to the different parts of the system, as much nutritive substance as the latter remove, and no more. In old age, however, the absorbents have greater activity than the agents of nutrition; the body usually becomes smaller in health, the various parts are weaker, capable of less exertion, and offering less resistance to injuries. The bones become more brittle, from the absorption of some of their constituent principles, and break more easily at that period of life than at mature age.

Every part of the body, as has been before remarked, is formed from the blood. The bones, though apparently so unlike this fluid, are secreted from it. If the food of a young animal be colored with madder, the bones will have a tinge of pink; if the animal take this food for a short time, then omits it, and then resumes it again, and so on, many times alternating in this way, it will be found, on killing the animal, and examining his bones, by sawing through one of the round ones, for example, that there will be concentric circles of white and pink osseous matter, corresponding with the manner in which the animal had been fed. This experiment

furnishes a decisive proof that the bones are constantly undergoing this double process of composition and decomposition; and so universal is this throughout the system, that the body can never be said to be identically the same that it was at any given time, however short, before. This change takes place more rapidly in some organs than in others, and more slowly in old than in young subjects. Among those whose size and physical properties are altered with rapidity, may be named the skin, the muscles, and the glands; while the tendons, the cartilages, and the bones, are changed much more slowly.

Many calculations have been made, to determine in what length of time the whole body is renovated; but no satisfactory results have been obtained. Some have supposed that it is accomplished in three years, and others have fixed the period at seven. This very difference is enough to satisfy any one, that the calculations are made without any data that can be depended on.

We know that this renovating power exists in much greater activity in the young than in the old. The length of time necessary to repair the various injuries which the body receives, is very different in the two. The bones in childhood unite in a few days, while in old age they require weeks to accomplish it, and, in some instances, so feeble are the powers of nutrition, that it is never effected.

It sometimes happens that the nutritive arteries have their action so much increased in some parts, as to produce preternatural growth. Of this character, are some of those tumors, called wens, which not unfrequently con-

sist of mere fat, the ordinary adipose substance. They apparently originate, merely from an increased action of those vessels, whose office it is to deposit the fat; there are other tumors, however, which consist of substances unlike any known to exist in the body. It sometimes happens also, that the nutritive arteries of a part take on a new action, and deposit not their ordinary substance only, but others which they have not heretofore secreted, but which are formed by the vessels of other organs of the body. It is in this way only that we can account for the depositions of bony matter that are frequently seen, sometimes on the inner coat of the arteries, about the heart, and even in the brain. In some diseases, as gout and rheumatism, chalky deposits are very frequently made about the small joints. These are sometimes as large as pigeons' eggs, and they are oftentimes so superficial, that by merely removing a very thin layer of skin that covers them, they can be used, when situated on the hand, for the purposes of marking or writing, as well as a piece of common chalk.

A question has arisen whether all the substances deposited by the nutritive arteries previously existed in the blood. The experiments that have been made to settle this point, are somewhat contradictory. Dr. Fordyce found that if canary birds were not supplied with lime in some form, about the period of their laying, they usually died. This he attributed to their not being furnished with the materials necessary to form the shell of the egg, and that the egg could not therefore be perfected. To a certain number of canaries he gave lime, at the period of their laying, which they swal-

lowed greedily, and all did well; to others at the same period he gave none, and many of them died. From this it might be inferred, that the nutritive vessels have not the power of furnishing the lime for the shell, unless it has been previously taken into the system. But the experiment of Vauquelin led to a different conclusion. He found that a hen, who took, in a given period, but 336 grains of calcareous and siliceous matter, formed during the same time 971 grains making a difference of 615 grains that must have been formed by the nutritive vessels.

It is very certain that no trace can be found in the blood of several of the secreted substances; but in those instances, in which these substances are of a compound character, it is not difficult to suppose that they are formed in the appropriate organs by a combination of their constituent elements. But this does not explain the formation by the secretory or nutritive vessels of some of the simple substances, or those which have usually been considered such, as lime and silica. Modern chemistry, it is true, has succeeded in decomposing them; but this does not remove the difficulty, unless it should appear that their elements have been taken into the system, either in the food or some other way. Of this, there was no evidence in the experiment of Vauquelin. It is impossible to say what new light further researches in animal chemistry may throw on this subject; at present, however, it is involved in great obscurity.

It was before stated, that the coloring matter of the skin was not subject to this process of composition and

decomposition; in other words, that it was not alternately deposited by the nutritive vessels, and removed by the absorbents, like most of the other parts of the body. This will perhaps explain the fact, which is familiar to all, that the marks made on the skin by Indian ink and some other substances, are permanent. They are probably introduced into the texture, in which the coloring matter of the skin is deposited, and as this texture has no absorbent vessels, there can be no way of removing the mark, but by cutting out the part.

We see, too, on the skin of negroes, that the scars of wounds of any considerable depth, are uniformly of a white color. The texture, in which the black pigment is deposited, having been destroyed by the wound, there are no means of regenerating it, and the part is supplied with the ordinary skin. All that is known on the subject of nutrition, may be stated in a few words. The various parts of the body, with but few exceptions, are furnished with nutritive arteries and absorbent vessels. The former have the power of depositing in the part to which they are sent, such substances as are adapted to their nutrition and growth. In cases of accident, by which any organ is injured, the nutritive vessels of the part take on an increased action, and deposit a much greater quantity of their ordinary secretion, in order to repair the injury. But how this is accomplished, or in what way vessels of apparently similar character, and circulating the same fluid, can deposit substances of very different characters in different parts, is wholly unknown.

Hitherto our attention has been engaged in the examination of the functions of organic life, those functions which are connected with the organization and growth of the body, and which the animal has, to a certain extent, in common with the vegetable. We have seen that the food is converted by the stomach into a homogenous mass, from which the first intestine extracts a fluid, that becomes assimilated to the blood, and ultimately forms a part of it. This fluid, having been prepared by the digestive process, is taken up by means of another, which is called absorption, and poured into the blood-vessels.

By means of the circulating system, it is first conveyed to the lungs, for the purpose of undergoing a change that is effected in it by respiration, and then, by another part of this system, it is distributed to all the organs of the body. That function, by which the nutritive parts are separated from the blood, and which is called secretion, has also been spoken of, and the various modes in which this function are performed have been noticed, and the purposes of the different secretions pointed out.

It is apparent that all these processes are intimately connected with, and have a mutual dependence on each other; and it is also evident, that they have a common object, which is the nourishment and growth of the body.

It seems wonderful that physiologists should seek to explain operations, so wholly unlike every thing that takes place in inert matter, by the known laws of chemistry and mechanics; but such is the fact. Digestion was for a time supposed to be the effect of mechanical

pressure, and when the present theory was adopted, it was called the theory of chemical solution, and Spallanzani, who did much to establish it, thought that it could go on, under certain circumstances, nearly as well out of the body as in. But facts do not bear him out; and though we may admit the power which the gastric juice has of dissolving food, it cannot be denied that it is a power which is in a great measure dependent on vitality.

Similar attempts have been made to explain the mode in which the other functions are carried on. The venous circulation has been said to be the result of the operation of the common principles of hydraulics; secretion has been called a sort of filtering; and the absorbents, we are told, take up their fluids by capillary attraction. That wonderful and mysterious change, which respiration produces in the blood, has been thought to be a mere chemical effect, and animal heat has been supposed to be the result of that process, by which this fluid is made to part with its latent heat. It is time that a different view was taken of this subject. There are other laws which have an influence in the animal economy, besides those of chemistry and mechanics, and these are the laws of vitality. They are not yet as well understood as those of the physical sciences; but we see operations going on in the living animal body, that cannot be explained by any known physical laws, and which sometimes seem to be at variance with them.

The functions of which we are next to speak, are those which connect man with external objects; and there is no ground for pretending that they have any

thing in common with those operations which are the effect of the laws of chemistry or mechanics. They are the functions which raise the animal above the vegetable, and which on the whole are enjoyed by man in a much higher degree than by any other created being: these are the functions of animal life.

We shall first speak of the nervous system and its functions, then of the senses and their organs, next of the voice and its organ, and finally of locomotion and its agents.

CHAPTER VIII.

OF THE NERVOUS SYSTEM.

The nervous system includes the brain, the spinal cord or marrow, the nerves, and the ganglions. The brain is a large organ, of a soft texture, occupying the whole cavity of the skull. It is of an irregular rounded form, with numerous convolutions and prominences, some of which have corresponding depressions in the bone, as if the shape of the brain was made to conform to the skull, though in fact there is no doubt that the brain gives the form to the bone. On its outer surface, it is of an ash color: this has hence been called the cineritious portion, and, from its position, it has been known under the name of the cortical part, as if it formed a covering to the whole, like the bark of a tree. The inner part is white, like marrow, and is called the medullary portion.

There are two great divisions of the brain; the larger, which is also the upper and front part, is called the cerebrum; the other, which occupies the back and lower part of the skull, is called cerebellum. Both of these are divided to a considerable extent into two parts, on the right and left, called hemispheres. The hemispheres

are separated by a strong, membranous partition or septum.

The brain has three membranes. One, which closely adheres to it, is of a texture so delicate, that it cannot be separated from it. The middle one has but little

THE UPPER SURFACE OF THE BRAIN.

firmness; but in some parts, it is so loosely attached, that it can be examined much better than the other. The outer one, which is next to the skull, is a strong, elastic membrane, and affords great protection to the

brain. There are four cavities within the substance of the brain, the precise use of which is not known. Some have supposed that they were formed for the purpose of allowing more space for the blood-vessels. During life, a serous exhalation is constantly going on in their interior, and in health, this fluid is probably absorbed nearly as fast as it is secreted. But it sometimes happens, in a diseased state of the organ, that this exhaled fluid accumulates and produces that formidable disease, known by the name of internal dropsy of the brain.

The cerebellum or smaller brain, is covered by a very firm membrane, which separates it from the cerebrum. The care with which the cerebellum is protected from injury is sufficient proof, if there were no other, of its importance in the economy. It seems to be an object to guard it from violent jars, and in some animals who are compelled to leap for their prey, this covering, which is a membrane in the human species, in them is formed of bone. The skull, which is opposite to the cerebellum, is also much thicker than at any other part, and a fracture at this place is more likely to prove fatal, than any where else on the head.

The brain is largely supplied with blood. Though in weight it constitutes but a fortieth part of the body, it receives, according to the calculations of some physiologists, a fifth part of the blood. This is probably exaggerated; but it is admitted by those who have doubted the correctness of this estimate, that at least a tenth part of all the blood is sent to it. It is certain that it is supplied by four large arteries; and the manner in

which these enter the skull, shows the necessity of defending the brain from any violent jar. The canals of these arteries are so curved, that the blood enters without producing any concussion of the organ. These great arteries freely communicate with each other soon after entering the skull; an arrangement, which is made, no doubt, to prevent the brain from losing any part of its supply of blood by an accidental obstruction of one or more of its arteries, which might sometimes occur from injuries of the brain, or the growth of tumors in that organ.

If the medullary part of the brain be hardened by artificial means, and then carefully scraped, there will be an appearance of fibres, which seem to diverge from the base of the brain. It is not yet settled whether these fibres actually cross each other, so that those from one side pass over to the other. That this does take place, seems probable from a circumstance which recently came under my notice. A young man fell with a piece of wire in his hand. This wire was very pointed at one end, and entered his brain directly above his eye. Neither the eye nor the optic nerve was injured: his senses were unimpaired, but the motion of the opposite side of the body was destroyed, though the sensibility remained. Leeches and other applications were made to the head, and, after a few weeks, the motion of the leg was restored; but that of the arm, though partially recovered, is still impaired, and it is now several months since the accident. This case certainly favors the opinion that the nerves of one side of the brain supply the opposite side of the body, and

render it probable, that the medullary fibres do actually cross each other.

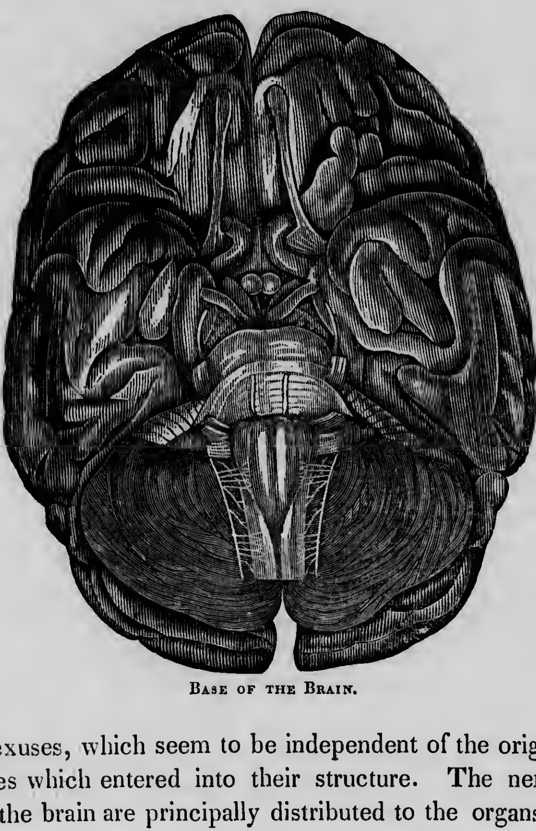
At the base of the brain, there is a small projection, which is called the pineal gland. It is worthy of notice, because Descartes supposed it to be the seat of the soul. It having been found to contain a few grains of earthy matter in the brains of some idiots, who were examined after death, it was at once inferred, that this earthy substance was the effect of disease, and produced the loss of mind. But it has since been ascertained, that it exists in the brains of all persons, though no one has as yet made a probable conjecture as to the use of it. By analysis it appears that this earth is principally lime.

The spinal cord or marrow is contained in a bony canal formed by the bones of the spine. It is, as it were, a continuation of the brain, and resembles it very closely in its structure. It is covered by a firm membrane, and the canal which encloses the whole, is so strong, and so well supported, that the injuries of the spinal cord are not very frequent.

The nerves are white cords of medullary matter, that are connected with the brain and spinal marrow. There are no less than twelve pairs from the brain, and thirty pairs from the spinal marrow. It has been usual, till recently, to say that there were but nine pairs of cerebral nerves, or nerves of the brain, but the subdivision that has been made of some of them, and which increases the number to twelve, is now generally adopted. All the nerves are enclosed in a sheath. Their fibrous

structure is more evident than that of the spinal cord, or even than that of the brain itself.

The nerves soon subdivide and communicate freely with each other, forming a sort of net-work, known by the name of plexus. New nerves go off from the



BASE OF THE BRAIN.

plexuses, which seem to be independent of the original ones which entered into their structure. The nerves of the brain are principally distributed to the organs of sense, and those of the spine to the muscular parts.

The ganglions are small bodies of a reddish color on the exterior, but white within, that are found along the course of some of the nerves. They resemble somewhat the brain in their structure, being composed of two parts of different colors. It is generally admitted that the nerves that go from them are larger than those that entered them; as if they imparted to the nerve some additional power.

This cursory view of the structure of the nervous system, may perhaps be sufficient to render more intelligible the account that will now be given of its functions.

The brain is the material agent of the mind, and it is also the organ which perceives the impressions that are made on the various parts of the body. The intellectual faculties and operations are so unlike the ordinary effects of matter, that it is not easy to believe that they are the result of any material organization. There must therefore be an immaterial something, which we call mind, and the brain is the instrument by which it operates. Of the mode of this mysterious connexion of mind and matter we know nothing; but we see abundant evidence of their reciprocal action on each other. Mental emotions and affections, if violent and long-continued, are not unfrequently productive of disease of the body, and a disordered state of the body oftentimes impairs or deranges the operations of the mind.

There is unequivocal evidence, then, that the brain is the organ of intellect. So strongly have many been impressed with this belief, that they have supposed that the mind was nothing more than the result of the organization of the brain; yet to this doctrine, the objec-

tion stated above seems to be unanswerable. But almost every day brings us additional proof that the brain is the organ of the mind. A blow on the head, if it produces a depression of a portion of the bone, and a consequent compression of the brain, is followed oftentimes by a total loss of the intellectual faculties. If the depressed bone be removed by an operation, the mind is restored to its wonted vigor.

Numerous cases of this kind are on record; but one of the most striking, occurred in the Mediterranean, in the year 1799. The patient was found on board the ship to which he was attached in a state of insensibility, but it was never ascertained how the accident occurred. He was first removed to Gibraltar, and thence to Deptford, and in May, 1800, was admitted into St. Thomas' Hospital, London. From the time of the accident to his admission into the Hospital, there was a complete loss of his mental faculties and bodily power. But he took food and digested it; the blood circulated freely, and the pulse was natural. His respiration was unaffected. On examination, it was found that a portion of the skull was depressed. This was raised by Mr. Cline. In a few hours, he gave indications of returning reason, and on the following day he spoke. In a short time he recovered entirely, and he had no recollection of any thing that that occurred from the time of the accident till the operation, a period of a year.

It was evident in this case, that the brain was the only part of the body that was affected, and that this affection consisted in a compression of the organ. It is certainly wonderful that this state of things having con-

tinued so long, did not produce some disease of the brain, of so serious a character as to prevent the recovery of the intellectual faculties.

The case of a beggar, who exhibited himself in Paris, has been frequently told. By some accident he had lost a portion of the skull; the brain at that place was covered only by its membranes and the common integuments, and for a trifling sum he would allow any one to press on this exposed part. As soon as the pressure was made to any extent, he became wholly unconscious, but his intellect was immediately restored when the pressure was taken off.

A violent concussion of the brain, without compressing or lacerating any part of it, is oftentimes followed by total insensibility. Patients sometimes remain in this state many hours, and even several days, and yet ultimately recover.

Injuries of no other part of the body, however severe they may be, produce the same effect on the mind. The intellect will remain unimpaired, so long as the functions of the brain are perfectly performed.

What part of the brain has the most intimate relation with the intellectual faculties is not known. It is certain that some portions are of less importance than others. The outer or cortical part is frequently wounded in accidents, and large portions of it are removed, without affecting the functions of the organ. Absesses and tumors form in the brain, and so long as they do not compress it, that is, so long as the absorption of the brain takes place as rapidly as the tumor or abscess is formed, the mind is unimpaired. It is not unfrequent

to see large pieces, not only of the outer, but of the medullary part of the anterior and middle portions of the brain removed by injuries, without destroying the life or impairing the intellect of the patient.

Though it may be considered as beyond controversy, that the brain is the organ of the mind, and that the intellectual functions will be more or less perfect according to the greater or less degree of perfection of the organ, yet we know not what constitutes that perfection. Some have supposed that the mind is in proportion to the size of the brain, when compared with the size of the body. This opinion was advanced by Aristotle, and has found advocates ever since his time. But this rule, though it may seem to be true in some instances, has so many exceptions, as to render it of no value.

It is true that the brain of man, whose intellect is immeasurably beyond that of all other animals, is very large in proportion to the size of his body, when compared with that of some animals with whom we are familiar. The human brain is four times as large as that of the ox, and yet the body of the ox is six times as large as the human body. But it has been found, on the other hand, that there are some animals, some species of singing-birds, for example, in whom the brain bears a larger proportion to the body than it does in man ; while some other animals, remarkable for their sagacity, as the elephant and the horse, have brains much smaller in proportion to the size of their bodies, than other animals of far inferior intellect.

Besides, the brains of infants, at a period when scarcely the slightest trace of intellect is discoverable,

bear a much greater proportion to the size of their bodies, than they do in after life, when the mind is fully developed.

The brain is also the organ which perceives the impressions that are made on all parts of the body. If, for example, the eye be ever so perfect, and the nerve which connects it with the brain, performs its functions, there will be no vision, unless the brain also acts. This is seen daily in disease. In dropsy of the brain, in which the origin of the optic nerve is compressed, though the nerve remains perfect and the eye uninjured, vision is lost. The brain is the centre of the nervous system; and all those actions originate in it which are performed by organs that are under the control of the will. It will be seen, that there is a set of nerves over which the will has probably no control, and this will explain the manner in which the various functions of circulation, digestion and respiration are carried on, when the brain is compressed, and the intellect gone.

The nerves are the agents of sensibility; that is, they convey to the brain the impressions which are made upon them. No other organs perform this office; but all the nerves have not this function, and some of them are destined for other important purposes. The usual division of the nerves has been into those of the brain, and those of the spine. There are twelve pairs of the former, and thirty of the latter. The nerves of the brain are distributed mostly to the organs of sense, and those of the spine to the muscles of voluntary motion. The first nerve of the brain goes to the organ of smell, and is called the olfactory nerve. The second

is sent to the eye, and is the optic nerve, the nerve of sight. The third, fourth and sixth pairs of nerves go also to the eye, but have nothing to do with the power of vision. They are distributed to the various muscles that move that organ. The fifth pair, which has three distinct branches, sends some of them to the eye, others to the nose, the jaws and the tongue. The nerves of this pair, which are sent, one to each side of the tongue, are probably the nerves of taste, or gustatory nerves. The seventh pair is the facial nerve, and is distributed to the muscles of the face ; the eighth pair, which, with the facial, was formerly called but one pair, is the auditory nerve. The ninth pair, generally known by the name of eighth, and also by that of the par-vagum, is now called pneumo-gastric, because it sends branches to the lungs and the stomach, and it sends others also to the larynx and the heart. The tenth pair is distributed to the tongue and the pharynx, the upper part of the gullet, and it is thence known by the name of glosso-pharyngeal. The eleventh pair, formerly called the ninth, is the lingual nerve, and is sent to the tongue. From its passing under this organ, it is also called hypo-glossal. The twelfth pair arises from the spine, but passes out through one of the holes of the skull, and is distributed to the muscles of the neck. It was formerly called the spinal accessory nerve of Willis. This last nerve, if we regard its origin, should be classed with the spinal nerves; but as it comes out with the nerves of the brain, it is ranked with those of that organ.

None of the nerves of the brain originate in the cere-

brum or cerebellum, but all arise from what is called the medulla oblongata. This is a portion of the brain, situated at the base, and between it and the spinal cord. The olfactory, the optic, and the auditory nerves, give off no branches till they arrive at the organs which they are destined to supply.

Thirty nerves on each side go off from the spinal cord, and all of them, like those of the brain, pass through bony canals. They are sent to the muscles of voluntary motion. It is necessary that the same communication should be kept up by the nerves, between the spinal cord and the parts to which its nerves are distributed, which is known to exist with regard to the brain. If the spine be fractured, so that the spinal cord is compressed, all the parts below the fracture are paralyzed. Sometimes the injury is in the lower part of the back, and the patient is only deprived of the use of his lower extremities; and though his recovery is hopeless, his life is not destroyed, and probably not shortened. In those cases, where the spinal cord is injured high in the neck, death does not always immediately follow; and while life continues, the mental faculties are unimpaired.

Sir Charles Bell has proposed an arrangement of the nerves according to their functions, which is equally remarkable for its truth and beauty. He divides the forty-two nerves that have been spoken of above, into two classes; those included in the first, he calls original, or symmetrical nerves, and those of the second, the superadded, or irregular. The symmetrical nerves are the thirty pairs of spinal nerves, and the fifth pair of the

brain; the irregular, or superadded, are the remaining nerves of the brain.

The symmetrical nerves have double roots, one arising from the hind part of the spinal cord, or medulla oblongata, and the other from the fore part. The posterior root has uniformly a ganglion. Those filaments which arise from the posterior root, form the nerves of sensation; and those from the anterior, constitute the nerves of motion. These nerves are given off with great regularity to each side of the body, and they are found in all animals, from the zoophyte to man.

The irregular, or superadded nerves, always arise from a single root; they are irregular in their distribution, and are superadded to the other system in greater or less number, in proportion to the degree of perfection of the organization of the animal, being found most numerous in man.

It has long been known that the medulla oblongata and the spinal cord are composed of three distinct sets of fibres or columns, the anterior, the posterior, and the middle. The nerves arising from the anterior, are the nerves of motion; those from the posterior are the nerves of sensation; and those from the middle are the nerves of respiration, or rather of respiratory motion. Those nerves of the brain which arise by a single root, are destined to one function only, and this function, whether it be that of sensibility or motion, is determined by the part of the medulla oblongata from which they arise.

No difference can be discovered in the structure of the several kinds of nerves, in any part of their course;

and the functions they are designed to perform, can only be known by ascertaining the place of their origin. Mr. Bell established many of the most important parts of his theory by very satisfactory experiments on living animals, and circumstances which are daily noticed in disease, tend very strongly to confirm his views. In the various forms of palsy, it is not unusual to see some parts deprived of all power of motion, while they at the same time retain their sensibility as perfectly as usual. This is remarkably illustrated in that paralytic affection, which is often seen in the face; the nerve affected is the facial nerve, a nerve of motion; and all the muscles to which it is distributed, are paralyzed, though their sensibility is unimpaired.

It would not be proper, in a work of this character, to follow Mr. Bell in the various explanations he has given, in illustration of his views of the nervous system. It is enough to say, that they fully establish the theory which he has advanced, and that the division which he has made of the nerves, according to their functions, has already been attended with practical benefits of no small value. A surgeon, for example, of the present day, would not propose, as has been done, to divide the facial nerve, for that painful disease, called tic douloureux; for he would know that this was a nerve of motion, and its division would be productive of no other effects than a paralysis of the muscles of the face to which it was distributed. The knowledge which may be derived of the functions of the nerves by carefully studying his theory, will be found useful in explaining various phenomena of the body, both in health and disease.

The nerves then may be divided into four classes: 1st., those of sensation, including those of the senses, and those of common sensation: 2d, those of motion: 3d, those of respiration or respiratory motion; and to these must be added a fourth class, being those which neither convey sensation nor motion, nor have any agency in producing the respiratory motions, but which serve to connect the various parts of the body into one whole, and are essential to its nutrition, growth, and existence. This last division is sometimes called the ganglionic system of nerves, as numerous ganglions are found in its course. It is also called the intercostal nerve, because branches of it pass off between the ribs; and as it forms a bond of union between the different organs of the system, it is frequently known by the name of the sympathetic nerve.

The origin of this nerve is somewhat doubtful. It has been supposed that the sixth pair of the brain furnished a small filament, which served as a rudiment for this system; while it has been asserted by others, that its first branch came from the spinal cord. It is seen in the upper part of the neck, within the sheath of the carotid artery: it soon passes out of that, and runs down along the spine, giving out numerous branches to all the organs of the chest and the abdomen, and communicating freely by small filaments with all the nerves in its neighborhood. The ganglions are very numerous along its whole course; so much so, in fact, that the nerve has been considered by many as a mere medium of communication between these different bodies.

The functions of the ganglions are not well understood. Some have supposed that they are intended to

limit the nervous influence; while others have thought, with apparently more probability, that it is rather their office to increase it. This seems probable from the fact that the nerves that go out of them, are larger than those that enter. Many have regarded them as smaller brains, independent centres of nervous power, formed for the purpose of placing the organs to the performance of whose functions they contribute beyond the control of the will. This opinion is perhaps received with more favor at the present day than any other, and there are several circumstances that render it plausible. It is very certain that the organs which they supply, perform their functions without any act of volition on our part; in fact, they go on almost, if not quite, as well while we are asleep as when we are awake, and no effort of our will can stop, retard, or interrupt them. All the secretions and all the various processes of nutrition, are wholly involuntary.

From this superficial view of the nervous system, the importance of its office in the economy must be apparent. It is the agent of the mind, and unless well organized, the intellectual faculties are imperfectly developed. It is the organ of sensation, and imparts to other organs the power of motion; for the bones and the muscles are but the instruments. If the nerve of a limb be divided, every part below the division is powerless. The eye and the ear may be ever so perfect, but the one cannot see nor the other hear without their peculiar nerve.

It is, in fine, the possession of the nervous system, that places animals above vegetables. The lowest

being in the animal kingdom has some nervous filaments which distinguish him from a plant, that is endowed with mere organic life. And as we ascend in the scale of beings, we see that the nervous system is more liberally dispensed as we advance, till we arrive at man, who possesses it in the greatest degree of perfection. It is true that some of the inferior animals may have the nerves of one or more of the senses somewhat more acute than those of man, but his nervous power, as a whole, is vastly superior to that of any other animal.

The elevated rank which man holds in the scale of being may be truly said to be owing to the exquisite structure of his nervous system. It has been justly observed, that all the 'faculties which elevate and dignify him, his reasoning power, his moral sense, his capacities of happiness, his high aspiring hopes, are felt, and enjoyed, and manifested, by means of his superior nervous system. Its injury weakens, its imperfection limits, its destruction, humanly speaking, ends them.'

CHAPTER IX.

OF THE SENSE OF SMELL.

Among the functions which connect us with external objects, none have a greater influence than those of the organs of the external senses. There are five in number, viz. those of smell, taste, touch, hearing, and sight.

The organ of smell is much more simple than those of some of the other senses, as those of hearing and seeing. The power of perceiving odorous bodies resides in the mucous membrane, called the pituitary or Schneiderian membrane, from the anatomist who described it, which lines the interior of the nostrils, and the cavities connected with it. There are four principal cavities; two situated in the upper jaw, and two in the prominent part of the frontal bone, directly above the eye. These cavities all communicate with the nostrils, and when odors of great pungency are applied to the nose, a sensation somewhat painful is felt, directly above the orbit of the eye. It sometimes happens, from inflammation and other causes, that the passage from the cavity in the jaw to the nostril becomes obstructed, and severe suffering follows. An opera-

tion becomes necessary: it consists in removing the tooth, which is situated directly under this cavity, making a perforation through the bone into it, and thus relieving it of its contents. The teeth which are contiguous to this cavity, are the large teeth, or grinders; but on account of their situation, they are not formed precisely like the corresponding teeth of the lower jaw. The lower teeth have but two prongs or fangs, which are long, and approximate each other at their lower end. The teeth, however, in the upper jaw, which are opposite to this cavity, have three fangs, which are shorter, and which also diverge more than the corresponding teeth of the lower jaw. The reason of this is apparent: if they were long, they would perforate the floor of the cavity of the jaw; and if there were only two short fangs, the tooth would not be sufficiently firm; but by having three, and all of them well separated, the teeth are as well secured as those of the lower jaw. This is an instance of that design which is so apparent in the construction of every part of the human frame.

The organ of smell is largely supplied with nerves. This sense is supposed to reside in the first pair of nerves of the brain, called the olfactory, which passes out of that organ through a thin plate of bone, perforated with holes like a sieve, and through each of these holes a nervous filament passes. These filaments cannot be traced to every part of the membrane; they have only been found in the upper and middle portion of it. This has led some to suppose that the other nerves, the branches of the fifth, which are sent to the nostrils, were also olfactory nerves, but this seems to be

doubtful; for we know that the sense of smell is much stronger in the middle and upper part of the nostrils that it is lower down, if it resides there at all. It is probable that the other nerves are merely nerves of sensation, and nerves of communication; that is, they serve to connect this organ with other parts of the body. There is a connection between the nerves of the nose and the nerves of respiration: this is sometimes seen in sneezing, which is a violent and sudden action of the diaphragm, the great muscle of respiration. This action is not unfrequently produced by irritating the nostrils by almost any stimulus to which they are unaccustomed.

The pituitary membrane is largely supplied with blood, and it is kept constantly moist by a mucus which is secreted on its surface. The tears also, which are not wanted for the purposes of the eye, are carried into the nostrils, through a passage called the nasal duct. This moist state of the membrane seems to be necessary to the perfection of the sense of smell: for it is always less acute, or disappears altogether if the membrane becomes dry from inflammation, or any other cause. This secretion is very copious, as evaporation is constantly going on with rapidity, from the air passing through the nostrils in respiration.

All odorous bodies throw off odorous particles. There is a great difference, however, among them in this respect; some throw them off under all circumstances; others only when they are moist, or heated, or in motion, or rubbed. These particles unite with the air, and are carried in the act of inspiration through the nostrils, and in this way are brought in contact with the

membrane in which the sense of smell resides. The secreted fluid which moistens this membrane, is supposed to have not only the power of rendering it more sensitive, but also of entangling, as it were, the odorous particles, and thus detaining them longer in contact with the minute filaments of the olfactory nerve. Odors are not ordinarily perceived, unless we respire through the nostrils:. there are some, however, so intense and pungent, as to affect the olfactory nerves, even if we do not inspire, unless we close the nostrils. But this is not usually the case: experiments show that if an opening be made in the wind-pipe, odors are not perceived so long as respiration is carried on through this artificial opening.

There is some reason to believe that the sense of smell does not reside in the cavity above the eye, nor in that of the jaw, though they both open into the nostrils and are lined with apparently the same membrane. In some cases, where these cavities have been open from accident or disease, experiments have been instituted which seem to have settled this point. Odorous vapors were introduced into them, and unless they passed into the upper part of the nostrils, they were not perceived. There is, in fact, but little doubt that the sense of smell exists only in the upper part of the membrane, in that part to which the olfactory nerve is distributed. When an odor is faint, and scarcely, if at all, perceptible, we draw the air forcibly through the nose, in the act of inspiration, and thus carry the odorous particles to the upper part of the organ. This we do instinctively; and the mere fact that instinct prompts us to do

it, is no small proof that it is the best way to accomplish the purpose we have in view. The odorous particles are in this way carried to the upper part of the membrane, which they might not otherwise reach, and strike it with some degree of force, and thus, as it were, make their presence felt.

Notwithstanding these views, however, there are some distinguished physiologists who are of opinion, not only that the sense of smell exists in the cavities of the jaw, and the frontal bone, but that the fifth pair of nerves furnishes the olfactory, instead of the first, as is generally supposed. It is very certain that in those animals in whom the sense of smell is remarkably acute, as the dog and the elephant, these cavities are remarkably developed. It is also certain, that in young children, in whom these cavities do not exist, the sense of smell is much less perfect than in after life. It is difficult, however, to believe, after the experiments that have been made on the subject, that the sense of smell does reside in them, though there can be no doubt that they contribute, in some way or other, very materially to the perfection of this sense.

Mr. Magendie has recently attempted to prove that the branches of the fifth pair of nerves are the olfactory nerves. But his experiments were made on living animals, under such circumstances as would justify no conclusion upon the subject, and ought not to weigh in the least against the mass of evidence that exists in favor of the old opinion.

The use of the nose seems to be to conduct the odorous particles to the olfactory membrane. Sir

Charles Bell maintains, that the form of this organ has nothing to do with the power of the sense. It is certain, however, that if it be removed by accident or disease, the individual is deprived of the sense of smell. Beclard states, what is certainly a very remarkable fact, that if he be supplied with an artificial nose, the sense will be restored.

The smell in man is not a sense of a high order. It is a source of pleasure, enabling us to enjoy agreeable odors. But its loss is not sensibly felt, nor does it cut us off from many enjoyments. It is possessed in a much higher degree by many animals; and the well-authenticated facts that are on record on this subject, would appear almost incredible to those who have had no experience on the subject. It has been stated as a remarkable fact, that those animals who, like the birds of prey, for example, uniformly feed on the most putrid and offensive substances, have the sense of smell in the greatest perfection. But there can be no doubt, from the avidity with which these substances are seized, that though to us they may be offensive and disgusting, they afford to them the highest enjoyment. Throughout the animal kingdom, we find that every tribe is adapted to its situation, and by a merciful provision, the moderate indulgence of the natural appetites is made a source of pleasure.

The sense of smell is somewhat under the control of the will; that is, we can use it more or less, according to the nature of the odors presented. We inspire forcibly, to enjoy the perfume of a rose; and we breathe

cautiously, or close the nostrils, if an offensive odor is presented to them.

This sense is, to a certain degree, susceptible of improvement. Long practice will enable individuals to discriminate various substances by the odor, when, to others, they all emit the same.

CHAPTER X.

OF THE SENSE OF TASTE.

The sense of taste resides in the mucous membrane of the tongue, the lips, the cheeks, and the fauces. Some have supposed that it exists in that of the gullet and stomach also; but this is not correct; for the nerve, which is now known to be the nerve of taste, is not distributed to these last-named organs.

Though the tongue is an important organ of taste, it is by no means the only one, as it has sometimes been thought to be. In those persons who have had this organ removed, the sense of taste remains. It is probable, however, that in these cases, the other parts have an increased sensibility, in comparison with what they before possessed. The tongue is a double organ, composed chiefly of muscles. The two sides are so perfectly distinct, that it is not unfrequent, in palsy, for one of them to be paralyzed, while the other remains perfect. Its surface is covered with little prominences called papillæ, which are supposed, by some, to have an erectile power; that is, to be capable of raising themselves, when savory food is brought in contact with them. The tongue is abundantly supplied with blood, having a large artery sent to each side of it. It is also

very largely furnished with nerves ; it receives branches from the fifth pair, besides the glosso-pharyngeal and the great hypo-glossal nerves, frequently called the ninth pair. Some uncertainty has existed, as to which of these was the gustatory nerve, or the nerve of taste. Recent experiments have proved satisfactorily, that the branch of the fifth pair, which is sent to the tongue, is the true gustatory nerve, and branches of it are distributed to all those parts in the neighborhood in which the sense of taste resides. It is not merely the gustatory nerve, but it is also the nerve of common sensibility.

The office of the glosso-pharyngeal nerve seems to be to establish a connexion between the tongue and the pharynx, the principal organ of deglutition, or swallowing. It is of obvious importance that these parts should act in concert ; and this can in no way be so well accomplished, as by distributing the same nerve to the two organs.

The hypo-glossal, or ninth pair of nerves, give to the tongue its power of motion. These nerves are very large, and the necessity of this is apparent, when it is recollected how numerous are the motions of the tongue, both in talking and in masticating our food.

The membrane, in which the sense of taste resides, is constantly covered in health by a fluid that is secreted by small follicles, situated in the substance of it. This is distinct from the secretions of the salivary glands, which aid materially in mastication and deglution of the food, though probably not in its digestion, while the mucus, that moistens the membrane of the tongue and mouth, is chiefly subservient to the sense

of taste. When this secretion is deficient, this sense is imperfect; and it is lost, when the parts in which it resides are deprived of their usual moisture.

This sense is closely connected with that of smell and that of touch. It resembles them both, in requiring to be in contact with the bodies, which produce the sensation of which it is the seat, and differs in this respect from the senses of seeing and hearing. It holds a much less elevated rank than the two latter. The enjoyments derived from it are strictly sensual and corporeal, and can in no way, like those of sight and hearing, be made to contribute to the enlargement of the mind. Its small importance, when compared with the two last named senses, may be inferred from the fact, that it is furnished with no nerve which is a nerve of taste only; for the branch of the fifth pair, which is the gustatory nerve, is also the nerve of common sensibility for the tongue. But the eye and the ear, on the contrary, in addition to an abundant supply of nerves of sensibilty, have also nerves, the optic and the auditory, which are exclusively nerves of sense.

The sense of taste is usually very acute in children. They prefer food of the mildest character, and have an aversion to every thing that is strong or pungent. This sense, as is well known, is capable of being much modified by habit: those articles which at first were disgusting, oftentimes become, by persevering in the use of them, highly agreeable. The use of tobacco is a striking example of this.

In connexion with the sense of taste, it may be proper to say a few words of hunger and thirst, though

they might have been noticed when treating of digestion.

Hunger is a peculiar sensation, seated in the stomach, arising from the want of food. When long continued, it is of a painful character. It has been explained, both on mechanical and chemical principles. It has been said to be owing to the opposite sides of the stomach rubbing against each other, when it was empty. A careful examination of the form and structure of this organ, would satisfy any one that this cannot take place; and even if it could, it is by no means probable, that the sensation produced by this friction, would at all resemble that of hunger.

The chemical theory is not much more plausible. It attributes the sensation of hunger to the corrosive action of the gastric juice on the inner coat of the stomach. But it is well known, that this fluid has no such action on any substance endowed with vitality.

The only satisfactory explanation seems to be that which supposes it to be a specific sensation, produced upon the nerves of the stomach for a particular purpose.

The sensation of thirst is usually thought to be seated in the mucous membrane, in which resides the sense of taste, and to be owing to a deficiency in the secretion of mucus which takes place in those parts. There is reason to believe, however, that its seat is more extended. An individual was wounded in the œsophagus, the passage which leads to the stomach; though his mouth was abundantly supplied with liquids, he suffered extremely from thirst. At length, fluid was conveyed

into the stomach through the artificial opening in the œsophagus, and the thirst ceased.

Hunger and thirst are classed among those affections called appetites; they are formed partly of a mental, and in part of a corporeal operation; they are designed to answer some important end in the economy, and they are brought about by the intervention of the nervous system.

CHAPTER XI.

OF THE SENSE OF TOUCH.

This sense is more extended than any of the others. It resides in the skin and the mucous membranes. It has been proposed to distinguish the sense of touch from that of feeling; but there does not seem to be sufficient reason to do this. They are both seated in the same organs, and have the same nerves, and the differences between them, appear to be only these: 1st, that the sense of feeling is more general, extending over the whole surface of the skin and mucous membranes, while that of touch is limited to particular parts, being in man most perfect in the hand: 2d, that the sense of feeling is passive, while that of touch is active.

As this sense resides principally in the skin, it is proper to give some account of the structure of this organ and its appendages.

The skin is divided into three layers; the outer of which is called epidermis, or cuticle; the middle, the rete mucosum; and the inner, the true skin, or vera cutis. Some have added a fourth, which has been called the papillary body. But this has not as yet been sufficiently examined, to enable physiologists to decide,

whether it should be considered a distinct layer, or only an appendage of the true skin, from which it arises.

The epidermis is a semi-transparent membrane, which seems to be destitute of blood-vessels and nerves: it is certain that neither have been discovered in it, and that it is totally insensible. It does not appear to be organized, like the other parts of the body, and it resists putrefaction for a great length of time, like inorganic substances. It contains numerous pores, but of so minute a size as not to be perceived by the strongest magnifying glasses. Yet there can be no doubt of their existence, and it must be through them that the perspirable matter passes.

The cuticle is seen to advantage, when a blister has been applied to the skin, and an effusion of water has taken place. The membrane that is raised up and contains the water, is the cuticle; and the fact that it can prevent the water from escaping, shows how very small its pores must be.

The cuticle is supposed to be formed by the vessels of the skin: it is a kind of exudation or secretion, which is readily formed, as we see how soon it is repaired, when any part of it has been injured or destroyed. Its purpose is evidently the protection of the parts beneath it. It is thin and delicate in those places that are not much exposed to accident, while it becomes exceedingly thick and firm where there is much pressure, as in the soles of the feet. Sometimes from disease, as scarlet fever and erysipelas, it comes off from the whole surface of the body, either in pieces of considerable size or small scales; and even in health, these

scales are constantly separating, especially from some parts as the head, though more gradually than from disease. It has been found to be composed chiefly of albumen.

The rete mucosum or mucous net-work is situated directly under the epidermis. It was first described by Malpighi, who supposed that it gave the color to the skin. Its existence has been wholly denied by some anatomists, while others have asserted that it may be found in Africans, and all other nations of dark-colored skins, but not in the European; while others have maintained the original opinion of Malpighi. The general opinion is now in favor of the existence of this layer, but its precise nature is not determined. Some have supposed it to be mere mucus, while others have thought, that it was a net-work of minute blood-vessels. Whatever it may be, it is certain that it is exceedingly delicate, so much so as not to prevent an intimate connexion between the cuticle and the skin.

The true skin is a membrane of considerable thickness, elasticity and strength. It is copiously supplied with blood-vessels and nerves. It is endowed with great sensibility, and though it varies in this respect in different parts of the body, it is upon the whole greater than that possessed by any other organ. In surgical operations, it is uniformly found that the patients suffer most pain when this part is cut through. When the skin is examined with a magnifying glass, small prominent points may be seen on its surface, which are called papillæ, and which some have proposed to consider as a distinct layer, under the name of papillary body. These papil-

læ are thought to be the termination of nerves, and the seats of sensation. The skin is connected on its outer surface with the cuticle, and beneath with the cellular membrane, with which it is so intimately blended, that it is not easy to say, where one terminates and the other begins. In addition to its numerous nerves and blood-vessels, it is abundantly furnished with absorbents, and the processes of exhalation and absorption go on in the skin to a great extent.

The skin is composed principally of gelatine, and on this account it is used in the manufacture of glue. When gelatine is united to tannin, a substance is formed which water cannot penetrate, and it is on this principle that leather is made. The skins are cleaned of their hair and other substances by lime-water, and then immersed in a strong solution of bark, which contains a large portion of tannin; a chemical union takes place between this and the gelatine of the skin; and if the process be well-conducted, and the skin be allowed to remain for a long time immersed in this solution, a leather is formed which will effectually resist water.

The nails and hair may be considered as appendages of the skin. The nails are intimately connected with the epidermis, and seem as if they were formed by an intimate union of several layers of this membrane. They are insensible, and their use is to support the pulpy part of the finger, when employed in the senses of touch. They are composed principally of albumen.

Each hair arises from a bulb or root situated under the true skin, which it passes through, as it does also through the epidermis. It is composed of two parts, an outer

covering, which is a tube, and a pulp which is contained in it. The hair, next to the bones, is the most indestructible part of the body. It possesses no blood-vessels, and it is destitute of sensibility. It has been thought by some, that in some forms of disease, blood-vessels enter it, and that it also becomes highly sensible. But the more prevalent opinion now is, that the blood-vessels do not extend beyond the bulb, and that the pain which is experienced when this is diseased, arises from its increased weight acting on the parts to which it is attached, and which, no doubt, are in a state of irritation.

It is not yet determined whether the color of the hair resides in the pith, or in the horny external tube that contains it.

The sense of touch has been thought to be the most certain of all the senses, because the objects which come under its cognizance, must be in contact with its organs. By it we require a knowledge of the physical properties of bodies, their shape, dimensions, consistence, weight, &c., and by it alone we are able to judge of temperature.

The sense of feeling resides in every part of the skin and many parts of the mucous membrane. The only thing necessary for its exercise, is that the body, on which it is to be exerted, should be in contact with it. No effort of the will is required; the sensation is produced as soon as the substance touches the organ of feeling. Though we obtain a knowledge of the temperature of bodies by the sense of feeling, we cannot acquire by it a correct idea of the actual heat of bodies.

Thus, any thing will feel warm to us, if it be warmer than the atmosphere, though it be in fact colder than our bodies. Cellars seem warm to us in winter and cold in summer, though their temperature is nearly the same during the year. The sense of feeling, therefore, gives an idea of the relative temperature of bodies, but not of their actual. This sense is not equally acute in all parts of the body. It is most perfect where the epidermis is the thinnest, as the impression must be made through this covering on the nerves beneath it. The great object of this covering appears to be, to blunt the impressions which foreign bodies would make on the nerves of the skin; and in those parts, as in the soles of the feet, where it seems desirable that but little, if any impression, should be made, the epidermis is very thick and firm.

The hand is the principal organ of touch, which resides in the greatest perfection in the extremities of the fingers. This organ is admirably adapted to its purpose. It is covered with a delicate epidermis, and abundantly supplied with blood-vessels and nerves. It has also numerous tendons, which enable it, under the guidance of the will, to execute an almost infinite variety of motions. When not in action, the hand has only the sense of feeling; but it is necessary to apply it to other bodies to bring into exercise the sense of touch.

Many, both among the ancients and the moderns, have been so much struck with the perfect mechanism of the hand, as to attribute to this source man's great superiority over other animals. But this opinion is not well founded. The hand is as perfect in the idiot as in

other individuals, and when it is destroyed, other organs, as the feet, acquire in a great degree most of its powers. The conclusion at which Galen arrived many centuries ago, seems to be the true one: that man had hands given to him, because he was the wisest creature; but he was not the wisest creature because he had hands.

The nerves which supply the sense of touch are the common nerves of sensation.

CHAPTER XII.

OF THE SENSE OF HEARING.

The organ of hearing is one of the most complicated in the human body. The precise office of the different parts is not yet known; it will be proper, however, to describe these parts in a general way, at least, in order to render intelligible what will be hereafter said on the sense of hearing. The different parts connected with this sense have been studied with much attention by anatomists; they have described them very minutely and distinguished them by names, not always very appropriate, but they have not been able to throw much light upon the subject of their use.

The organ of hearing may be divided into the following parts, viz. the outer, the middle, and the inner part, and the auditory nerve. The outer part consists of the external ear, and the tube which leads to the membrane of the tympanum. The external ear is composed chiefly of cartilages, covered with a delicate skin, and largely supplied with nerves and blood-vessels. It has several prominences and depressions, each of which has a distinct name, and also some muscular fibres. It has been thought that these muscles, if they had not

been prevented from acting at an early age by bandages, &c. applied to the head, would have been under the control of the will, and been able to move the external ear, and shut and open the entrance to the passage at pleasure. But this is not probable, for savages, whose heads are not subjected in infancy to any of the restraints which civilization imposes, have not this power, nor do we observe it in infants before any application is made to them.

The external ear, when well formed, inclines a little forward, and is admirably adapted to collect sound, which it transmits through the tube that leads to the membrane of the tympanum. This tube is nearly an inch in length, and is formed in part of cartilage, and in part of bone. It has a number of small glands or follicles which secrete the wax, and its entrance is guarded by stiff hairs, to prevent insects and other foreign bodies from entering. These, however, do not always answer the purpose for which they seem to be designed, for insects sometimes get into the ear and produce great pain. This pain is owing to the extreme sensibility of the membrane of the tympanum; but when it is recollected that this membrane has no opening, it must be apparent that the apprehension that is often expressed lest the insects should penetrate farther, is wholly groundless.

The middle part of the organ of hearing embraces the tympanum and its membrane, the small bones of the ear, or ossicles, as they are called, and the Eustachian tube. The membrane of the tympanum is situated at the bottom of the external passage or tube, and is covered on

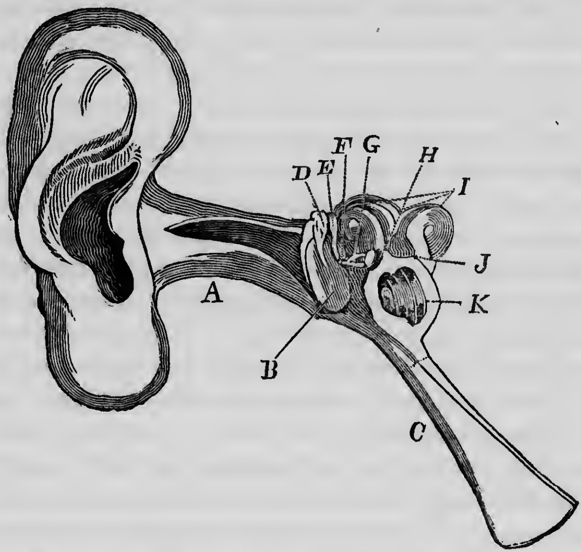
its exterior by a thin delicate skin, the same that lines the tube. Its inner surface is covered by a mucous membrane, and a nerve, known by the name of the chord of the tympanum, passes over it. To this inner surface also is attached one of the small bones of the ear. This membrane is placed obliquely, inclining downwards and inwards; it is tense, thin, and transparent.

The tympanum is a cavity situated between the external and the internal ear. It is of an irregular, cylindrical form, with several openings, some communicating with the internal ear, and one which is the termination of the Eustachian tube. It also contains the four little bones of the ear, known by the names of the hammer, the anvil, the round bone, and the stirrup. These bones are all connected together: the end of the hammer is attached to the membrane of the tympanum, and the stirrup is placed over an opening which leads to the internal ear. Muscles of very small size are inserted into these bones, and move them in various directions.

The Eustachian tube leads from the back part of the throat, or fauces, as they are called, to the cavity of the tympanum. It is about two inches in length; partly bony and partly cartilaginous. It is lined by a mucous membrane. Its two extremities are not of the same size, the one opening in the fauces being somewhat larger than the other.

The internal ear is situated in a part of the temporal bone, near the base of the skull, which, from its stony hardness, has been called the petrous portion. It is composed of three parts, the cochlea, the vestibule, and the semicircular canals. The cochlea is so called from its

resemblance to the shell of a snail. It is situated near the entrance of the Eustachian tube, and is the most anterior part of the internal ear. It communicates with the cavity of the tympanum and the vestibule. The vestibule is situated in the central part of the internal ear, and is, as its name imports, a sort of porch or entry, which communicates with all the other parts. By



A MAP OF THE EAR. *A* The external auditory tube. *B* The membrane of the tympanum. *C* The Eustachian tube. *D* The hammer. *E* The anvil. *F* The round bone. *G* The stirrup. *H* The oval opening. *I* The semicircular canals. *J* The vestibule. *K* The cochlea.

means of the oval opening, (the foramen ovale) it communicates with the tympanum, and over this opening is placed the small bone called the stirrup (stapes). It has communications also with the cochlea, the semi-

circular canals, and internal auditory tube, — the one through which the auditory nerve passes to the internal ear on its exit from the brain; and it is through the openings which lead from the vestibule to the internal auditory tube, that the branches of the auditory nerve go to the various parts of the internal ear.

The three semicircular canals are situated behind the cochlea and the vestibule, and they all terminate in the latter. There is found in them a dark greyish semi-fluid substance, the use of which is unknown.

The auditory nerve is a branch of the seventh pair, called the soft portion, or portio mollis: the other, which is distributed to the face and known by the name of the facial nerve, is called the hard portion, or portio dura. The auditory nerve passes into the internal auditory tube, and is subdivided into numerous small filaments, which pass through minute openings, and finally terminate in the form of a pulp in the various parts of the internal ear.

Hearing is that function by which we obtain a knowledge of the vibratory motions of bodies. When these motions are produced, undulations in the air follow, which are propagated in all directions, and which, when they strike upon the ear, cause what we call sound. Air is the most common vehicle of sound, though all elastic bodies, whether solid or fluid, are capable of conveying it. Water is a better conductor of sound than air, and some solids better than either. If two stones, for example, be struck together under water, a person whose head is under the surface may hear the sound at a great distance. If a slight scratch be made on one end of a long stick of timber, and the ear be applied to the other, it will be heard very distinctly. It is

a knowledge of this principle, of the propagation of sounds by solids, which has led to the formation of what are called stethoscopes, the instruments which are now used by physicians to obtain farther light on various diseases. One end of them is placed on the surface of the body over the diseased part, and the ear is applied to the other; the sound that is propagated through them is carefully noticed, and an opinion is formed from the character of this of the probable nature of the affection. It is obvious that these instruments are not adapted to all cases; they are chiefly used in affections of the organs of the chest, the heart, and lungs.

The vibrations of a sonorous body will not affect the sense of hearing, — or, in other words, will not produce sound, unless they take place in a medium that is able to propagate them. Thus, if a bell be struck under the exhausted receiver of an air-pump, no sound follows.

Though sound is enfeebled by passing from one medium to another, still it can be propagated from the air to the water. If a musket be discharged over a person, who is under water, he will hear the report, if he be within a moderate distance. But a question has arisen, whether sound when thus propagated from the air to the water, can be propagated from the water to the air again. As for example, whether the discharge of a musket over a diving bell covered with water could be heard by the persons in the bell; that is, whether the sound could be propagated from the air to the water, and from the water to the air in the diving-bell? With a view of deciding this question, I descended in company with three other persons in a diving-bell, twenty feet below the surface of the water, and remained there

more than forty minutes. While we were in the bell, a musket was several times discharged directly over it, but we heard not the slightest sound. A musket was again discharged, when we were ascending: at the moment the top of the bell rose above the surface of the water, we heard the report distinctly, and even thought it nearly as loud as usual.

Sound is capable of being reflected, and the angle of reflection has been ascertained. An echo is produced by a reflected sound, and it is on a knowledge of this principle of the reflection of sound, that whispering galleries are constructed. The same remark applies also to ear trumpets.

The velocity with which sound travels can be readily estimated. Repeated experiments have shown that it is, under ordinary circumstances, at the rate of eleven hundred and forty-two feet in a second. A knowledge of this fact enables us to decide with ease as to the distance of a thunder-cloud during a thunder-shower. If the interval that elapses between the flash of the lightning and the report of the thunder be carefully noted, the calculation is of course easily made. It is very common, during the discharge of artillery, to see the flash some seconds before the report of the cannon is heard. In this way, the distance of a ship of war at sea has been determined by those on board the vessel she was in pursuit of, and the expediency of coming to, or striking has been decided.

The precise office of all the different parts of the organ of hearing is not known. The purpose of that part of the external ear, which projects from the head,

seems to be to collect sound; and it is well adapted for this purpose, and for reflecting it into the external tube. It is not, however, essential to hearing, as it has been removed, in man and some other animals, without destroying or materially impairing this sense; and some animals, as birds and moles, are destitute of it, and yet have the sense very perfectly.

The external tube simply transmits the sound, which has been received by the external cartilage. The wax, which is found on its surface, is supposed to be intended for the same purpose as the hairs placed at its entrance; that is, to prevent the introduction of foreign bodies into it.

Great pains have been taken to ascertain the use of the membrane of the tympanum. It would seem to be important, from its situation, and from its connexion with the other parts of the organ. It is tense and dry, and therefore well calculated to transmit the impressions that are made upon it to the air contained within the tympanum, and thence to the various parts of the internal ear. It possesses great sensibility, and has a nerve running across it, as has been before stated, called the chord of the tympanum. Muscular fibres have been discovered upon it, and Sir Everard Home, who first described them, suggested that the membrane might be the part appropriated to the reception of musical sounds. But this hypothesis was soon overthrown, by a communication made to the Royal Society, by Sir Astley Cooper, in which he stated, that a patient, who had the membrane of one ear entirely destroyed, and that of the other much injured, retained his power of

perceiving musical sounds unimpaired. It is certain, that whatever may be its functions, they continue to be perfectly performed after it has been ruptured. Many persons can force smoke from the mouth, through the ear, which they could not do, if the membrane of the tympanum was whole, and at the same time they possess the sense of hearing in full perfection.

The use of the tympanum is supposed to be to transmit to the internal ear the vibrations made on the membrane. This is done in part by the air which it contains, in part by its walls or parietes, and above all, by the chain of small bones, that were spoken of before. One of these, the hammer, or malleus, is attached to the membrane of the tympanum at one of its extremities, and at the other, to the anvil or incus : this latter bone is connected with the round bone, or os orbiculare ; and this again with the stirrup, or stapes, which is placed over the oval opening, the foramen ovale, that leads to the vestibule. When, therefore, the membrane of the tympanum is acted upon by the vibrations of the air, it is thought that these bones are moved in such a way as to communicate these vibrations to the internal ear. But it is evident, that our knowledge on this subject is not very precise, from the fact that all these bones, except the stapes, may be lost, as they sometimes are from disease, and the individual will for some years after retain the sense of hearing.

The use of the Eustachian tube is more apparent. It is to admit the air to the cavity of the tympanum, and thus keep its membrane in a proper state of tension, and render the pressure on both sides equal. It

undoubtedly performs an important part in the function of hearing. If it be completely closed, deafness ensues. This explains why we are deaf, from a cold in the head. The end of the Eustachian tube, which opens in the back part of the throat, is obstructed by an inflammation of its lining membrane, and the air consequently is not freely admitted into the cavity of the tympanum. Many cases of deafness arise from a permanent obstruction of this tube. A knowledge of this fact, led Sir Astley Cooper to propose an operation for this species of deafness. He knew that many persons heard perfectly well, though the membrane of the tympanum had been ruptured; and he believed that the deafness from an obstruction of the Eustachian tube, arose from the circumstance that the air was not admitted to both sides of the membrane of the tympanum. He therefore proposed to puncture this membrane, and he performed the operation several times. At first, it was thought to be attended with some degree of success; but the deafness soon returned, in nearly if not all the cases, and the operation is now abandoned.

But little is known of the use of the internal ear. Books on physiology abound with speculations on this subject: distinct offices are assigned to the different parts, but it is the result of conjecture merely. Many have supposed that the cochlea performed a very important part in the function of hearing; but Vicq-d'Azyr, in a memoir on the ears of birds, maintains that they are not furnished with it, and yet many of these animals possess this sense in a high degree. All that is certainly known

respecting the internal ear, is, that the auditory nerve in a soft, pulpy state, is expanded in the semicircular canals, the cochlea and the vestibule; and it is probable, that, from their bony structure, they have the power of modifying the vibrations made on the membrane of the tympanum, which might otherwise be too powerful.

The auditory nerve, which is a branch of the seventh pair, is a nerve of special sensibility, destined to this one purpose only. It has been ascertained by experiments, that it is entirely destitute of ordinary sensibility; that it can be cut, pricked or torn, without producing any pain. The nerves which furnish the ear with the ordinary sensibility, are derived from the fifth pair.

The sense of hearing is next in importance to that of sight. Considering the ear merely as the instrument which makes us acquainted with sound, its place cannot be supplied by any other organ. It opens to us sources of intellectual enjoyment, thus furnishing another example of the goodness that directed the formation of our bodies, by making the ear tributary to our pleasure, while it is at the same time instrumental to our comfort and convenience. This sense becomes much more acute, when that of sight is impaired or destroyed. By it, the blind judge with great accuracy of the distance of bodies in motion, the width of streets, and the height of buildings. It is capable of improvement, even when all the other senses are perfect. By habit, we learn to judge of the distance and direction of bodies, by the sense of hearing ; and the savage, who has improved this sense to a high degree, in pursuit of his enemy or his game, will distinguish sounds that are inaudible to civilized man.

CHAPTER XIII.

OF THE SENSE OF SIGHT.

The eye is the organ of sight; but in order to give a correct idea of the function of vision, it will be necessary not only to describe this organ, but its various appendages. The apparatus of vision is somewhat complicated; but the uses of the various parts are much better understood than those of the organ of hearing.

The eye is an optical instrument of the most perfect construction. It is of a globular form, composed of a number of humors, so called, which are covered by membranes, and enclosed in several coats. These humors are called the vitreous, the crystalline, and the aqueous. The vitreous, which takes its name from its resemblance to melted glass, is situated in the back part of the eye, and constitutes the greater portion of the globe. It is of the consistence of the white of an egg, and is contained in numerous small cells, formed in a membrane of great delicacy, which also covers it. On its anterior surface, there is a slight depression, and in this is situated the crystalline humor or lens. This is a body of considerable thickness and strength; it is in the form of a double convex lens, the convexity of the

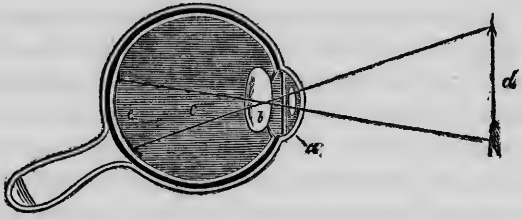
two sides, however, is not the same. It is placed in a perpendicular direction, immediately behind the pupil, and is kept in its situation by a membrane, which is called its capsule. When macerated, it has been found to consist of several layers, which increase in thickness towards the centre. The analysis of Berzelius has ascertained that the materials of which it is composed, contain the same properties as the red globules of the blood, without the coloring matter.

In front of the crystalline lens, and occupying the whole of the anterior part of the eye, is the aqueous humor, the only one of the three which is entitled to the name of humor. It is composed principally of water, with a few saline particles, and a very small portion of albumen.

A curtain, with an opening in its centre, floats in the aqueous humor, but is attached to one of the coats of the eye at its circumference. This curtain is called the iris, and the opening in it is the pupil. It derives its name from the various colors it has in different individuals, and it is the color of the iris that determines the color of the eye. There is considerable diversity of opinion as to its intimate structure: some have thought it to be a mere continuation of one of the coats of the eye, others have supposed it to be a peculiar texture, and others again are of opinion, that it is formed in part from one of the coverings of the eye, and that it has also a layer peculiar to itself. The back part of the iris is called the uvea. The iris divides the space between the crystalline lens and the front of the eye into two parts, called the anterior and

posterior chambers, the former of which is much larger than the latter. All the light admitted to the eye, passes through the opening in the iris, and it is supplied with muscular fibres, by which this opening can be dilated and contracted.

The eye has three coats or coverings. The outer, which is called the sclerotic, is a firm, fibrous membrane, which serves to defend the eye from injury, and into which the muscles, that move it in various directions, are inserted. It extends over the whole of the eye, except the fore part, where a transparent membrane, called the cornea, is situated. It is the sclerotic coat that is known by the name of the white o the eye.



A SECTION OF THE HUMAN EYE. *a* The aqueous humor. *b* The crystalline lens. *c* The vitreous humor. *d* is an object from which the rays of light go off, and as they enter the eye, they are refracted by the different humors, and form an inverted image, *c*, on the retina.

Within the sclerotic coat is situated the choroid coat. It is a thin, delicate membrane, composed in great measure of blood-vessels and nerves. It is loosely attached to the sclerotic coat, which it covers, and is of the same form and extent. On the surface of the choroid coat is found a dark substance, called the black

pigment, which is of great importance in the function of vision.

The inner coat of the eye, if it be not an expansion of the optic nerve, is composed of nervous filaments, and is called the retina. It is of the same extent as the other coats, surrounding the whole globe of the eye, except the circular opening in front. To the edge of this opening, the circumference of the iris is attached; — the band which connects it is known by the name of the ciliary ligament — and over it is placed a convex, transparent membrane, called, from its resemblance to horn, cornea. It was formerly supposed that this was but an elongation of the sclerotic coat: it has been, however, ascertained, that this is not the case, and that it can be separated from it by maceration.

The optic nerves are the second pair of the brain. Before they enter the eye, they come in contact, their fibres seem to intermix; and it has been thought, by some, that the nerve of one side is sent to the eye of the opposite side. This, however, is not the case.

The optic nerve does not enter the eye in the centre, but at a short distance from it on the side towards the nose. It is not the nerve of sensibility; it is destined to one function only, that of sight. The eye is abundantly supplied with nerves, both of sensibility and motion, from other sources.

The importance of the eye is obvious, from the manner in which it is guarded from injury. It is situated in a deep, bony socket, with a prominence above, on which is placed the eyebrows: it is furnished with lids, which can be shut so closely, as to exclude not

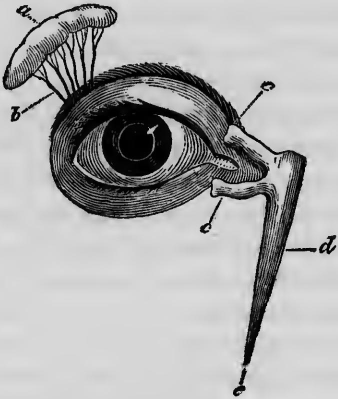
only foreign bodies, but even the light, when it is too intense. There is also an apparatus for the formation of tears, with which the eye is washed, and by which foreign particles are removed from it.

The eyelids are two in number in man. They have a thin, delicate skin on the outside, muscular fibres beneath, and a cartilage on their edges. They are lined by a mucous membrane, which passes from them over the anterior part of the eye, which is called the tunica conjunctiva, because it is the tunic which connects the eyeball with the lids. It is loosely attached to the lids, so as to allow free motion in all directions.

In the edge of the lids are numerous small glands, which secrete an unctuous substance, that is probably expended on the eyelashes.

The tears are secreted by a small gland, called the lachrymal gland, situated within the orbit of the eye, at its outer angle. This secretion goes on while we are asleep, as well as when we are awake. The eye is kept constantly moist. When the tears have performed their office, they pass through two small openings, one in each eyelid, called puncta, and are thence conveyed into the nose. It has been usual to call the upper part of this canal, the nasal sac, and its continuation, the nasal duct. But there seems to be no reason for this distinction, as the canal is of nearly the same size throughout its whole extent. It not unfrequently happens, that this canal, from inflammation and other causes, becomes obstructed, particularly in that part that leads into the nose. The tears flow over the cheek ; the upper part of the canal swells, inflames,

and finally bursts, and in this state it constitutes the disease which is known by the name of fistula lachrymalis.



a The lachrymal gland. *b* Its several ducts, to convey the tears to the eye. *c c* The puncta. *d e* The nasal duct.

The eye has six muscles, which are attached to the outer coat, and which give it almost every variety of motion. They are among the most curious parts of the mechanism of the organ of sight.

Having thus taken a general view of the eye and its appendages, let us next examine the office which the different parts perform in the function of vision. It is this function that makes us acquainted with light and the color of bodies ; it aids us too in forming an idea of their size, figure, and distance. But this function cannot be exercised without the stimulus of light, a subtle fluid, which is constantly emanating from all lu-

minous bodies. Light is not homogeneous, but is composed of seven different colored rays: these rays cannot be decomposed. It is by a knowledge of these facts, that the variety in the colors of different bodies is explained. A white body, for example, reflects all the rays; a black one absorbs all; and a colored body reflects some, and absorbs others. These rays of light enter the eye, and form upon a certain part of it the image of the body, from which they go off; when the mind perceives this image, vision takes place. When the rays strike upon the cornea, the transparent membrane situated in the front part of the eye, some of them are reflected, which gives the eye its lustre and brilliancy, and the others pass through it. In thus passing from a rarer to a denser medium, that is, from the air into the aqueous humor, the rays are refracted; and it may be said, that it is among the uses of the cornea, the aqueous humor, the crystalline lens, and the vitreous humor, to refract the rays, and to concentrate them on the retina.

It is the province of natural philosophy, rather than of physiology, to enter minutely into the theory of vision. It may, however, be observed, that the laws of optics teach us, that the rays of light passing through an optical instrument like the eye, must produce an inverted image of the object, from which the rays proceed. And this is found to be true, by experiment. If the sclerotic coat be removed from the back part of the eye of an ox, and the eye be placed in a hole in a shutter, by looking through it in this situation, the images of the objects seen will be inverted on the retina.

The more recent experiments of Magendie have fully confirmed the prevailing opinion.

The principle office, therefore, of the cornea, the aqueous humor, the crystalline lens, and the vitreous humor, is so to transmit and refract the rays of light, as to produce the most perfect image on the retina. But there are other parts, whose office is essential to the correct performance of this function. The iris, the beautiful curtain which is attached at its circumference to the circular opening in the coats of the eye, and which floats in the aqueous humor, has a slit in its centre, through which the rays of light must pass, before they can reach the retina. It is furnished with muscular fibres, by which it can contract and dilate this slit, so as to exclude or admit the light, and regulate the quantity of it. This opening in the iris is called the pupil, and the variations in its size, according to the degree of light to which it is exposed, is a subject of common observation. If it be too much contracted, or too much dilated, vision will be imperfect. When we go from a dark place to one where the light is strong, we at first see but imperfectly, because the pupil had been very much dilated while in the dark, in order to allow as many rays of light to enter the eye as possible, and it cannot instantaneously accommodate itself to the great increase of light, so that we do not see, from the mere excess of the very cause which produces vision. The reverse also is true. Every one's experience teaches him, that he sees much better in a dark night, after he has been some time in the dark, than he did at first, because the pupil has become much more dilated, and, of course, admits more light.

The pupil can be so much dilated as to completely destroy vision while the dilatation continues. There are various substances that can produce this effect, when taken into the stomach or applied upon the skin. If the extract of Stramonium, the common Apple Peru, be mixed with water, and applied to the skin around the eye, the pupil will become extremely dilated, and remain so, as long as the Stramonium is kept on. Oculists make use of a knowledge of this fact in some of their operations, particularly for that of cataract. This disease is an opacity in the crystalline lens, or its capsule, or both. Couching consists in depressing this opake lens, and thus removing the obstruction to the rays of light. It is desirable in this operation not to injure the iris, which is apt to fall in front of the couching needle, if much of the aqueous humor escapes. By applying the Stramonium, a short time before the operation, the pupil is dilated, or, in other words, the iris retracts, so as to be less exposed to injury. It is obvious that if this operation be completely successful, the eye is not as perfect as if it had never been diseased, and of course the vision will not be as good, for an important part of the crystalline lens has been removed. It is therefore necessary for those who have undergone this operation to wear convex glasses, which in some degree compensate for the loss they have sustained.

The use of the choroid coat, is to absorb the rays of light immediately after they have passed through the retina, which it is able to do by means of the black pigment on its surface. Were it not for this provision, the

light would be too intense, and vision would be indistinct. In those animals who see only by night or very imperfectly by day, it has been found that their eyes are not furnished with this pigment. The same deficiency exists in the eyes of albinos; and it is well known that they see more distinctly with a small than with a large quantity of light. Some white animals with red eyes, as white rabbits and white mice, have the same defect of vision from the same cause.

The office of the retina is to receive the impression of the rays of light, and it is upon it that the image is formed. It may therefore be considered the seat of vision; but this does not take place without the action of the optic nerve and the brain: the nerve conveys the impression to the brain, and the brain perceives it. But how all this is accomplished we know not. It is the result of vital action, which we can neither imitate nor understand.

The retina was formerly supposed to be endowed with extreme sensibility; but recent experiments have shown, that it is almost insensible to every stimulus but that of light. The same is true of the optic nerve. Branches of the fifth pair furnish the eye with the ordinary sensibility, and several pairs of nerves are distributed to its muscles.

There are some circumstances connected with vision that may be thought worthy of notice. It is well known that a separate image is formed on each eye, and that if the eyes be not in the same direction, the objects will appear double. This is easily proved by pressing one eye, so that the rays of light cannot enter

it in the same direction as they do in the other: two objects will then be seen, or double vision, as it is called, will be produced. This affection arises from a variety of causes: it is sometimes the effect of tumors, which grow in the socket and press against the eye-ball; and sometimes it is the result of an affection of the brain in consequence of injury or disease.

It is well known, however, that the eyes of persons who squint are not in the same direction; and it is also well known that they see but a single object. Physiologists were for a long time puzzled to explain this apparent contradiction, and they are indebted to Buffon for a solution of the difficulty. In squinting, both eyes are not directed to the object, and one eye only sees. If the individual saw with both, there would necessarily be double vision. The cause of squinting is a weakness or imperfection of one of the eyes; and if it had the same direction as the well eye, it would therefore produce imperfect vision. To avoid this, it is unconsciously turned to one side, usually towards the nose; and this, before long, gives the eye permanently that direction.

When the weakness of the eye is not very great, and the individual who is thus affected is young, the difficulty can sometimes be removed. If the well eye be covered, the other sees, and takes its natural direction. and it may not unfrequently be kept so, by compelling the individual to use only the weak eye for a length of time.

It is not rare to meet with individuals whose eyes are so singularly constructed, that they see best at night,

or in a very feeble light. They are called nyctalopes; and this peculiarity is owing to a deficiency of the black pigment of the choroid coat. It has been found that this pigment is more abundant and of a darker color in the eyes of those persons who reside in countries in which they are exposed to a strong light, than in those who reside in countries where the sun is not so powerful. The pigment is very dark in the eyes of birds that are much exposed to the rays of the sun, while it is entirely wanting in the owl.

By attending to the structure of the different parts of the eye, and considering the manner in which the image of luminous bodies is formed on the retina, it is not difficult to explain the cause of that very common defect known by the name of short or near-sightedness, The individuals, who labor under it, cannot see objects distinctly, unless they are brought near the eye. The reason is, that there is too great a degree of convexity in the cornea, or the crystalline lens, or the vitreous humor, or all of them, and the rays of light are too soon brought to a focus; in fact, before they reach the retina. This defect is in a great measure obviated by the use of concave glasses.

Long-sightedness is of course an opposite defect, and it is one which most people experience after middle life. The different parts of the eye are not sufficiently convex, the rays are not brought soon enough to a focus, and an indistinct image is the consequence; convex glasses, it is well known, are used with great advantage in these cases.

The sense of sight contributes more to the enjoyment and happiness of man than any of the other senses. It

is indeed a subject of astonishment, that an instrument so curiously constructed as the eye, many parts of which are so delicately formed, and requiring as it does for the performance of its office the co-operation of so many distinct and dissimilar portions, should be able for so long a time to perform its functions. It is not a matter of surprise that so many are deprived of sight: on the contrary, it is wonderful that so many continue in the enjoyment of it, when we consider the almost numberless accidents to which this organ is exposed.

CHAPTER XIV.

OF THE VOICE.

The voice is a sound produced in the wind-pipe by the air in its passage to and from the lungs It is, however, most usually produced in the act of expiration. Though it is intimately connected with respiration, this alone cannot produce it. The functions of the lungs may be perfect, and yet the animal may be destitute of voice. Its organ is the larynx, and of the structure of this we shall now attempt to give some description.

The larynx forms the top of the wind-pipe, and is consequently situated in the upper part of the neck. It is attached above to the bone of the tongue, and behind it is connected with the œsophagus, the passage to the stomach. It is the larynx which makes that remarkable prominence that is seen in the neck, particularly of men, and which is called Adam's apple, *pomum Adami.* The larynx is composed of four cartilages loosely connected by membranes, and a fibro-cartilage. The cartilages are the thyroid, the cricoid, and the two arytenoid, and the fibro-cartilage is called the epiglottis. The thyroid or scutiform cartilage, so called from its resemblance to a shield, constitutes the front and lateral

part of the larynx. It is larger than the other cartilages, broader in front than behind, and composed of two parts, with flat surfaces on the side, which unite at an acute angle in the front of the neck, forming the prominence spoken of above. Behind, it has two projections at its upper part, which are connected with the bone of the tongue, and which are called its upper horns or cornua. It has two others below, which are united by ligaments with the cricoid cartilage, and which are called the lower horns, or cornua.

The cricoid cartilage takes its name from its resemblance to a ring. It is situated below the thyroid cartilage: it is narrow in front, broader at the sides, and still broader behind, where it is connected with the thyroid cartilage. It is not in contact with this cartilage in front; the space is occupied by the lining membrane of the larynx, and covered by the common integuments. It is in this space, that an opening is frequently made for the removal of foreign bodies, that accidentally get into the wind-pipe.

The cricoid cartilage rises up considerably behind on each side, and on each of these eminences there is a smooth surface, on which are situated the arytenoid cartilages. They are placed at the back part of the larynx, and are much smaller than the cricoid cartilage. When the larynx is examined from behind in the dead body, before any of the parts are removed, the arytenoid cartilages form a single eminence, with a concave surface above, and resemble in appearance the mouth of an ewer, from which they take their name. They are loosely attached to the cricoid cartilage, and have muscles which move them in a lateral direction, and it is

by their motions that the opening in the larynx, called the glottis, is enlarged and contracted. The arytenoid cartilages are connected with the thyroid by means of four fibrous ligaments, the two lower of which are called chordæ vocales, or vocal chords, as they perform an essential part in the production of the voice. They are about half an inch in length, and arise from the anterior prominence of the arytenoid cartilages, and pass horizontally forwards and inwards, to the angle formed by the junction of the two sides of the thyroid cartilage, and there meet together. The space between these two ligaments, is the glottis, or rima glottidis, or chink of the glottis; for it is called by all these names in anatomical descriptions.

At a short distance above these vocal chords are two others, running nearly in the same direction; and the space between them and the lower chords is called the ventricle of the larynx.

The epiglottis is situated between the larynx and the root of the tongue. Its shape has been said to resemble that of a myrtle leaf. In the ordinary state its position is perpendicular, but in the act of swallowing the tongue goes back, the epiglottis which is attached to it is thus brought over the glottis, whence its name, and the food is in this way prevented from passing into the wind-pipe. As soon as swallowing is effected, the tongue ceases to press upon the epiglottis, its elasticity restores it to its former position, which it is important for it to preserve, except in the act of swallowing, in order to allow a free passage for the air to the lungs.

The resources of nature are strikingly displayed, when, as sometimes happens, the epiglottis is destroyed

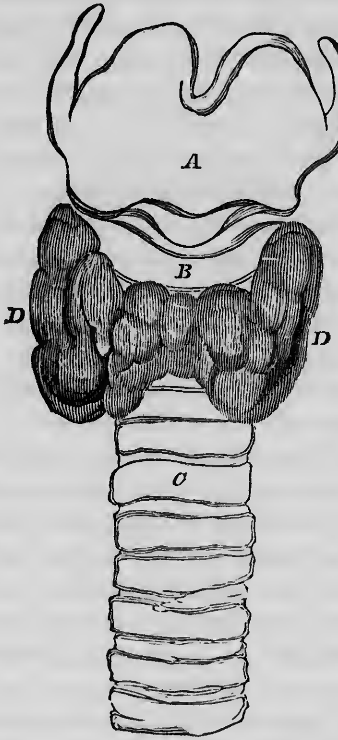
by disease. It, no doubt, under ordinary circumstances, prevents the entrance of food into the wind-pipe in the act of swallowing; but those patients who have lost the epiglottis have still the power of swallowing, though in an imperfect degree. Magendie, who removed this little organ in some experiments on animals, found that they could swallow, and that the food was prevented from entering the wind-pipe by the contraction of the vocal ligaments, which closed the glottis.

The larynx is supplied by four nerves, all furnished by the par vagum, or eighth pair; two are called the superior laryngeal, and are sent off in the neck, and the other two are called inferior laryngeal, or more commonly the recurrent nerves, because the par vagum does not give them off, till it has passed the larynx and entered the chest.

In front and somewhat below the larynx, is situated a body, called the thyroid gland, the use of which is not known. It consists of two lobes, one on each side, which are united together in the middle. It is very largely supplied with blood, having four arteries, two from the external carotid, and two from the subclavian. There is no evidence that it performs the functions of a gland, as no excretory duct has ever been detected going off from it. It is of a very variable size in different individuals: it is usually larger in females than in males, and it is the seat of that singular and anomalous disease, so prevalent in some countries, which is known by the name of goitre.

The larynx is undoubtedly the organ of voice. If an opening be made in the wind-pipe, the voice is lost:

if this opening be closed by the hand, or any thing that shuts it completely, the voice is restored. We see



The larynx and trachea seen in front, in outline. The thyroid gland is shaded. *A* The thyroid cartilage. *B* The cricoid cartilage. *C* The trachea. *D D* The thyroid gland seated below the larynx, and embracing the upper part of the trachea.

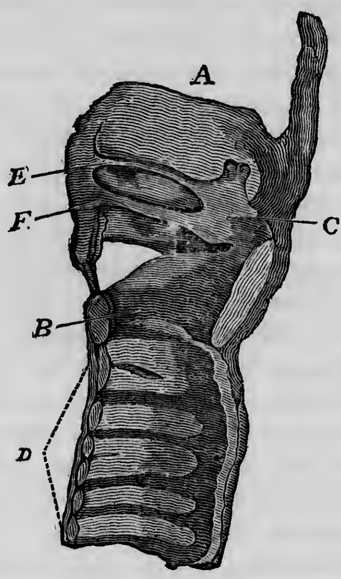
this frequently in persons who attempt to commit suicide, but who only wound the wind-pipe, or the larynx, without cutting any important blood-vessel.

It is also proved by experiment that the epiglottis is not concerned in the production of the voice. An incision was made in a living animal between the os hyoides, the bone of the tongue, and the thyroid cartilage, and through this opening the epiglottis was drawn out: the animal retained his voice. It has also been ascertained, that the voice is not lost when the epiglottis is confined or even cut away. Its office seems to be only to guard the wind-pipe against the introduction of foreign substances into it whilst swallowing.

The voice, under ordinary circumstances, is produced during the act of expiration, that is, as the air is passing out of the lungs; but this alone is not sufficient for its production; if it were, breathing would be always accompanied by a vocal sound. But this is not the case, for the voice is under the control of the will, and respiration is in great measure involuntary. We can, to be sure stop our breathing for a time by our volition; but we know that respiration goes on as well when we are asleep, as when we are awake, and when of course there is no effort of the will on our part.

Experiments have also satisfactorily shown, that nearly all the larynx, except the chordæ vocales, could be cut away, without destroying the voice. These chords, it will be recollected, passed from the arytenoid cartilages to the thyroid cartilage, and are what are sometimes called the lower vocal chords. It is obvious therefore, that these chords perform an important, if not the principal part in the production of the voice. The precise manner in which this is accomplished is not known, but the explanation given by Magendie is

perhaps more satisfactory than any other. The air, in passing from the lungs in expiration, is forced out of small cavities, as the air-cells and the minute branches of the wind-pipe, into a large canal; it is thence sent



A section of the larynx and part of the trachea. *A* The thyroid cartilage. *B* The criceid cartilage. *C* The arytenoid cartilage. *D* The cartilaginous rings ef the trachea. *E* The superior thyro-aryteneid ligament, extending from the thyreid to the aryteneid cartilage. *F* The lower thyro-aryteneid ligament er vecal chord. Between these ligaments is the ventricle of the larynx.

through a narrow passage, on each side of which is a vibratory chord, and it is by the action of the air on these chords that the sonorous undulations are produced which are called voice.

The larynx has been examined in a living animal, and at the moment he uttered his cries, it was seen that the upper chords were unaffected, while the lower ones distinctly vibrated.

It has been objected, however, to this theory of the voice, that when air is forced from the trachea through the larynx in a dead animal, the voice of the animal is not produced. It has to be sure been maintained by some writers, that it can be produced in this way; but this statement is not credited at the present time. In fact, numerous experiments have been made on the subject, which show conclusively that no sound follows, unless the arytenoid cartilages are brought in contact with each other. But, admitting that the voice does result from the vibration of the vocal chords, it does not follow that it could be produced when air is forced through the trachea and larynx of a dead animal. The production of the voice is not a mechanical process, which can be easily imitated, but it is a vital function, executed by living agents, under the direction of the laws of vitality, and the result of a voluntary action. Even in the living animal, the voice is lost if certain muscles be paralyzed. If both the recurrent nerves be divided, this effect follows. This fact shows conclusively that the vocal sound depends upon the vocal chords; for these cannot vibrate without the contraction of the thyro-arytenoid muscles, and to these muscles the recurrent nerves are sent. It is the office of these muscles, which go from the thyroid to the arytenoid cartilages, to move these latter cartilages, and, in so doing, they put in a state of tension, the lower vocal

chords, which are also attached to these cartilages. Thus it appears that the voice is lost, when its organ is apparently perfect, and the air passes through it as usual, merely because two small nervous chords at a distance are divided; and yet it is a matter of astonishment to some, that they cannot produce the vocal sound by forcing air through the trachea and larynx of a dead animal.

There can then be no doubt as to the nerves of voice; they are the recurrent nerves, which are given off by the par vagum in the chest, and are distributed to those muscles, which move the arytenoid cartilages in such a way as to produce a tension of the vocal chords. It seems singular that there should have been any question on this subject in modern times; for Galen, who lived seventeen hundred years ago, divided the recurrent nerves of a pig, and thus deprived him of voice. The same result has been obtained more recently in experiments made on different animals. Magendie found that if both the recurrents were cut, the voice was immediately lost, and if but one were divided it was partially destroyed.

It has been a subject of controversy among physiologists, whether the larynx was a wind or a stringed instrument. The question is still unsettled, but there seems to be no reason why it may not partake in some measure of the character of both.

There are two kinds of voice, the natural and the acquired. The former is possessed by the inferior animals as well as man; the latter is enjoyed to any extent by man alone. The natural voice consists in mere

cries, without any articulate sound. It is possessed by the infant as soon as it is born, as well as by idiots, and those who are dumb from their birth. It is dependent on organization only, and not at all upon the intellect or the sense of hearing. The larynx is the exclusive organ of this voice.

The acquired voice is the result of imitation, and enables us to give utterance to articulate sounds or words. The child soon learns to imitate, the sounds which he hears; but those who are born with great imperfection in the organ of hearing, never learn to speak; they are dumb because they are deaf, and not because there is any defect in the organs of speech. The faculty of speech cannot be acquired if there be no sense of hearing, or if the intellectual faculties are wanting; hence we see that those who are born deaf are dumb, and that many idiots are also dumb. The want of intellect is no doubt the reason why infants do not speak at an earlier age, for they have the organs of voice in perfection, as well as the sense of hearing. There are some animals, as the orang-outang, who have the organs of speech as well developed as they are in man, but who are never able to acquire the faculty of speech. The reason which has been assigned for this by Dr. Gall, seems to be a satisfactory one, and that is, that it is owing to their want of intellectual faculties.

In the acquired voice, some other organs besides the larynx are brought into exercise, as the tongue and the lips ; but neither of them are essential to the faculty of speech. There are a few letters, called labials, which cannot be well sounded without the lips ; but many

cases are on record, which prove that articulation remains perfect after the tongue has been removed. I can also bear witness to this fact.

The acquired voice or speech, and the construction of language, are among the strongest evidences of the superiority of man's intellect over that of other animals, and enlarge, perhaps more than anything else, his capacity for enjoyment.

The acquired voice is susceptible of a great degree of cultivation. By practice, many persons learn to imitate the voices of other individuals, and even of other animals. Ventriloquism, as it is called, is perhaps among the most curious modifications of the voice. Persons who practise this art, endeavor to inspire the belief, that in doing it, they do not use the ordinary vocal organs. But this is not the case ; the effect is produced chiefly by the power they possess of modifying the voice according to circumstances.

Ventriloquism consists in making the voice of the performer appear to proceed from other persons in various places, either in or out of the room. To do this, he first directs the attention of his audience to the place where the person, who is about to speak, is supposed to be : he next produces such a modification in his voice, as would make it sound like the voice of a person at the distance at which the speaker is supposed to be ; and he also avoids the use of those words which have labials, and which would of course require the use of his lips. Let us suppose, for example, that he has stated that the person, with whom he is about to converse, is in the cellar : he addresses him in his usual tone of voice; but

when he comes to reply for the man in the cellar, he changes his voice, and gives it such a sound as it would have, if it had come from one speaking there, and at the same time avoids the use of the labials. This can only be acquired by long practice, and by those who have a strong faculty of imitation. Other explanations, and some of them partaking of the marvellous, have been given of this talent: the one just stated, is that of Magendie, and seems at least to be highly probable.

CHAPTER XV.

OF LOCOMOTION AND ITS ORGANS

It is by the power of locomotion, that we are able to change our place. This power, perhaps, connects man more intimately with the external world, than anything else. It of course enlarges his sphere of action, and increases his means of acquiring knowledge. It distinguishes him from vegetables; for though many plants, particularly some of those of the sea, are not attached to the spot where they originated, they do not possess, in the proper sense of the term, the power of locomotion. This implies volition, and may be said to be the result of a voluntary contraction of the muscles.

In those functions which relate to the nourishment and growth of the individual, the animal is passive; digestion, absorption, the circulation of the blood, and secretion, go on without any act of the will; in fact, they are not under its control, they cannot be stopped, if we would. They are, therefore, organic functions, connected with the mere organization of the body, and which we possess in common with vegetables.

But the functions of the brain and nervous system, those of the organs of the external senses, and that of

the voice, as well as those of the agents of locomotion, are strictly animal functions ; for they are possessed by animals alone, and vegetables do not partake of them in the least degree.

The bones and muscles are the agents of local motion; but they can do nothing, unless they are supplied with the nerves of voluntary motion, and these are under the influence of the will. But in addition to the bones and muscles, there are another set of organs that are intimately connected with them: these are the ligaments. The ligaments are strong fibrous bands, which connect the bones with each other in many parts of the body. They allow the joint, where it is required, great freedom of motion, as we see in the knee and shoulder joints. They are white membranes, of great strength, and endowed, in health, with but a very slight degree of sensibility.

In considering the means by which locomotion is accomplished, the bones, muscles, and ligaments may be regarded as the mechanical agents, and the brain and the nerves as the vital ones. The nerves convey the stimulus of volition to the muscles; they in consequence contract, the bones serve as levers, and, being connected with each other by ligaments, form joints or hinges, and the whole machine is thus put in motion under the guidance of the will. This power of contraction, or contractility, as it is called, is possessed by the muscles alone, and is one of the most remarkable properties of life. It performs an essential part in many of the functions of the body. It is by the muscular fibres in the iris, that it is able to contract, when exposed to too

much light; and it is the muscular power of the heart, which enables it to throw the blood with such force through the arterial system.

The muscles are of various forms in different parts of the body. They are composed of numerous fibres, which are connected together by cellular membrane. They constitute a great part of the bulk of the body. It has been a subject of controversy among physiologists, whether muscular contractility was derived from nervous influence, or whether it was a property inherent in the muscles. The latter opinion was maintained with great ability by the celebrated Haller; but the prevailing sentiment is now in favor of the other; though some recent experiments of Dr. Philip, show that the question is not yet considered as absolutely settled.

When a muscle contracts, its fibres shorten, and become harder, as may be easily ascertained by placing one hand on the inside of the arm, and then bending the elbow. The muscle on the inside will be felt to contract and to become exceedingly hard. The power with which a voluntary muscle contracts, is very various: it depends, of course, upon the will. Under some circumstances, it is much greater than under others: when the individual is insane, or under the influence of strong and exciting passion, as anger, his muscles seem to be endowed with preternatural power. The knee-pan is frequently fractured by muscular contraction alone. The fact that we are able to raise great weights, is another evidence of the extent of this power; for this must be effected by the contraction of the muscles. Some of the inferior animals possess this

power in a higher degree than man. Some insects, it is said, are able to carry a piece of lead equal to their bodies in size.

The length of time in which a muscle remains contracted, is various. The duration of the contraction of the voluntary muscles, is in some degree under the control of the will; but it cannot be continued indefinitely; relaxation must follow. The duration of the contraction is also in some measure in an inverse proportion to its force: if a muscle has contracted with great violence, relaxation will take place sooner than when the contraction has been less powerful. The muscles, which produce the various motions of the body, are so arranged, that while some contract, others are relaxed; and if this were not so, it must be obvious, that continued locomotion could not be effected.

The velocity of the muscular contractions is dependent on the will. Though many of the voluntary muscles in man contract with great rapidity, those of some other animals far surpass them in this respect. A race-horse, it is said, has run a mile in a minute, though it is not pretended that he could continue at this rate, even for a second minute. But rapid as this is, it is far inferior in velocity to the flight of birds and insects.

Muscular contractility is the property which produces all the motions of the animal machine. It generates power, and therefore differs essentially from any known mechanical property. In the best contrived machinery, no power is really generated; but the effect produced, is the result of the application of a pre-existing power. Contractility, on the other hand, produces power, by

the mere effort of the will; and though the animal motions are frequently made on mechanical principles, they are not always so. The muscles are in some instances attached to the bones which they are to move, not in the way best adapted, according to the laws of mechanics, to gain power. It is obvious that all the movements of the animal machine are directed by something more than mechanical principles, and these are the laws of vitality.

The various attitudes and motions of the body are the result of the contractile power of the muscles. We cannot be in that common attitude of standing on both feet, without putting this power into requisition. The body is prevented from falling, by the effort of the muscles alone. The base of support is small, being only that space on which the feet rest, and that which is between the feet. The larger the base, the more secure will be the position; so that those who have small feet, do not stand so firmly as those with larger ones, and those who have lost a part of their feet, stand still less securely than either. The smaller the base, the greater must be the muscular effort to preserve the attitude; hence the difficulty of standing on our toes, or of walking on a rope.

The bony structure, which constitutes the solid part of the frame, is composed of a variety of distinct pieces. These are connected together by ligaments and muscles, which allow of a greater or less degree of motion. The muscles that pass from the spine to the head, prevent it from falling forward, as it would do were it not for them. This we see daily. Persons who get to

sleep, while sitting or standing up, do not keep the head erect : it falls directly on the breast. The same thing occurs when a person is suddenly deprived of his consciousness and power of volition, as by palsy or apoplexy ; the head invariably falls forward.

The spine is also supported by the power of the muscles ; the same is true of the thighs, the legs, and the feet. Habit and instinct teach us which position of the feet renders us most secure in the erect attitude. That has been said from observation to be so, in which the feet are placed parallel to each other, with a space between them equal to the length of one of them. If the feet are more separated, we become more secure in the lateral direction, but more inclined to fall forwards and backwards.

Walking consists in a succession of steps. Let us suppose a person to be standing in the attitude spoken of above ; that is, with his feet parallel to each other, and that he wishes to go forward. To accomplish this, he first raises the thigh, by the contraction of the powerful muscles which go from the body, and which are inserted into it. By thus bending the thigh, the leg is carried forward ; the foot is then brought to the ground, which the heel first touches. The body is then partially rotated on the head of the thigh bone, which is fixed, of the foot that has just been advanced ; the other thigh is raised in the same way as the first was, at the same time that the body is rotated, so that the leg is carried forward, and the foot can be put down at the side of the other, or in advance of it. This completes a step, and it is obviously the result of muscular power, under the guidance of the will.

In the act of *leaping*, the body is raised from the ground, and, for a very short time, is suspended in the air. When we wish to leap directly forward, we bend the head upon the body, the body on the thighs, these on the legs, and the legs on the feet. The feet too do not stand firmly on the ground, as when we are about to walk ; the heel only slightly touching it, or not touching it at all. All the muscles, in fact, that are concerned in the act, are in a state of flexion. They are then suddenly and simultaneously contracted with great force; by this contraction, the feet are not only raised from the ground, but, as was explained when speaking of walking, are carried forward. When the body is thus thrown forward, it is governed by the laws which govern all projectile bodies; it is carried to a greater or less distance, in proportion to the power with which it is projected, and it is brought back to the earth by the law of gravitation. The muscles which act with the greatest power in leaping, as they must raise the whole body, are those of the leg, that large mass of flesh known as the calf of the leg. They are admirably fitted for this, both from their size, and the manner in which they are attached to the heel. The body is not carried forward by any direct impulse ; on the contrary, the retraction of the head and the spine would have a tendency rather to throw it backwards ; but the rotation of the thigh bones has an opposite effect : it is sufficient not merely to counteract the powers that are exerted in a different direction, but also to carry the body forwards ; it is the action of the muscles of the leg that carry it upwards. The length of the leap must depend, if other things be equal, on the length of the thigh bones.

The arms are of some use in the act of leaping. They are brought to the side of the body, when all the joints are in a state of flexion; but the instant the feet are raised from the ground, they are thrown out. They thus resist the muscles which have a tendency to raise them up, and thus add the power of these muscles to those which are exerted to raise the body upwards. The ancients understood this, and it was customary for the leapers among them to hold in their hands, weights which were called *halteres.* We see in our own times that persons, who are about to leap, take in their hands some heavy substance, as bricks or stones.

Hopping is merely leaping on one foot. The body cannot of course be thrown so far in this way as in leaping, as the muscles of one leg only are exerted.

Running consists in a succession of short leaps, executed by each leg alternately. It differs from walking in two respects: 1st, that the body is carried forward as each leg is advanced; 2d, that before the foot that is advanced has reached the ground, the other is raised from it. A momentum is in this way acquired at each additional leap, which has the effect of preventing us, when we are running rapidly, from stopping in an instant, as we can do when we are walking.

There are numerous other attitudes and motions of the body that might be considered under this head; but these are sufficient for our purpose, which was to show that they were all produced by the action of the voluntary muscles.

CHAPTER XVI.

OF THE DECAY AND DISSOLUTION OF THE BODY.

All organized beings have a limited period of existence. This is longer or shorter, as the vegetable or animal arrives later or earlier at its maturity. The oak, which is years in attaining its growth, is for ages the tenant of the forest; while those plants and animals, which are brought to their full perfection in a few days or weeks, decay and die in a period equally short.

The organs of the human body do not arrive at maturity so soon as those of most other animals, and of course the duration of man's existence is longer than that of most of the inferior orders of the animal kingdom. The elephant and some other animals, however, surpass him in this respect.

The various functions of the human body bear a very different relation to each other at the different periods of life. Before the body has attained its maturity, all the nutritive functions are in great activity; digestion, absorption, and nutrition are rapidly performed. The brain and nervous system, which impart vigor to them all, are more developed in proportion, than in the subsequent periods of life. When the body has arrived at its full growth, an equilibrium seems to be established, and for some years the balance is preserved.

Why should not this state of things continue? Why should not the body go on and perform its various functions for an indefinite period, if not prevented by accidental circumstances? We can discover nothing in its structure that renders its decay inevitable. To us, judging only from what we know of its organization, there seems to be no reason for its decline and dissolution, if it be carefully guarded from injury. We know that there is in the system, a power of repairing many of the injuries which the body receives; if it were not so, wounds would never heal, a slight cut would produce a fatal bleeding, and the ends of a broken bone would never unite. But the moment any of the organs are injured, a process is commenced for their restoration. There seems to be a sort of conservative principle in the system, which in some measure guards it from the effects of our imprudence, and repairs the injury which it may in any way sustain. But notwithstanding the apparent perfection of the organization of the body, and the efforts which it has the power of making to remove the effects of violence, it will decay, be the exertions ever so persevering and well-directed, that are made to guard it. It cannot be said that its early death is to be attributed to civilization; to the circumstance that man does not adhere to the mode of living which was intended by his Creator; for it is certain, that in a civilized state, man arrives at a much greater age, and retains for a longer period all his faculties, than in a savage one. Civilization, so far from having shortened the term of human existence, has undoubtedly lengthened it; and that state seems to be the

most natural for man, in which he surrounds himself with the greatest means of rational enjoyment, by the exercise of his intellectual and bodily powers.

But in this state, the corporeal organs, though they be carefully watched, constantly preserved from injury and exempted from disease, will gradually but steadily decline after adult age. All the organs do not fail at the same time; those, which are essential to the mere nourishment of the body, are the last to feel the influence of age. The nervous system is among the first to lose its vigor. The senses of seeing and hearing become dull, and perception is blunted. The powers of locomotion are impaired. The muscles contract feebly, and remain constantly in a state of partial flexion, which renders them unable to support the body perfectly, and gives an attitude of stooping. The step is less firm and frequently becomes tottering, so as to render the aid of a staff necessary. All these effects are the result of an enfeebled state of the nervous system.

As age advances, the circulating system performs its functions less perfectly. Bony matter is deposited in various parts of it; the valves of the heart and many of the arteries become ossified, so as to interfere essentially with the free circulation of the blood.

The purpose of respiration is not perfectly effected in consequence of the state of the lungs, or the minute capillaries which carry the blood into them. At any rate, breathing does not produce in this fluid the complete change which it does at an earlier period.

The three great systems therefore, the nervous, the circulating, and the respiratory, all become affected by

age, but not all at the same time, nor in the same order of succession in different individuals. So intimate is their connexion, that whichever is affected, the others are sure to suffer, and the functions of all are before long equally embarrassed. When the organs are in this enfeebled state, it requires but little to stop their action, and this is frequently done by accidental causes, which at an earlier period would seem trifling. The powers of vitality are so feeble in old age, that they are unable to make any effort to relieve the system, and what would at one time have been a temporary suspension of the action of some of the organs, now produces a cessation of the functions of all, which is death.

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